The financial implications of regenerative agriculture in the Southern Cape and the subsequent impact on future animal and winter cereal crop production.

By

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Declaration

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Abstract

Dryland farming systems in the Southern Cape are largely reliant on external inputs to function in a financially feasible manner. In recent years, the prices of key farming inputs have begun to put financial pressure on farming systems in the Southern Cape. A trial was recently started in the Southern Cape to assess soil regeneration and the impact thereof on future crop and livestock production. The trial was used as a point of reference in this study to simulate potential production scenarios. Regenerative agriculture shares selected principles with other farming practices such as conservation agriculture (CA) but emphasises biomimicry over external inputs. The aim of this study is to conduct explorative research on the financial implications of future regenerative farming practices in the Southern Cape. A proposed result of the long-term implementation of regenerative farming practices in the Southern Cape is the establishment of agricultural practises that are well adapted to internalise the impacts of changing weather patterns and harmful farming practises.

The explorative nature of this study was well suited to the use of simulation modelling where hypothetical changes can be made to the typical conservational farming system in the Western Rûens homogenous farming area, to gain insight into the possibilities surrounding purely regenerative farming practices. A multidisciplinary group discussion was held to incorporate expert knowledge and producer experience on possible production scenarios concerning various purely regenerative farming practices. The concept of the typical farm was applied as a theoretical tool to simulate various production scenarios that CA-like farming systems in the Western Rûens homogenous farming area may face when converting to purely regenerative farming practices. A whole farm multi-period budget model was constructed based on information collected by a local business, during the group discussion and various direct communications. The net profit value (NPV) and the internal rate of return (IRR) are indicators of whole-farm profitability and were used to conduct the relevant financial assessments.

Four scenarios based on regenerative principles were assessed according to the financial implications imposed on the IRR and NPV of a typical farm. Scenario planning was used to apply the various changes to the initial state of the typical farm and to assess the financial implications of a percentage change in the IRR and NPV on whole-farm profitability in the subsequent state. The initial state of the typical farm simulated had an IRR of -3.22% and an NPV of -R66 405 812.70. An annual reduction of 10% in the amount of inorganic nitrogen applied, a carrying capacity of 5.5 SSU/ha, a sliding feed scale and a crop/livestock ratio of 70/30 were the most profitable changes made to the typical farm over a period of 20 years. Changes made to the machine inventory had a negative effect on whole-farm profitability. The

accumulative changes made to the typical farming system had a positive effect on whole-farm profitability. The IRR and NPV of the typical farm in its subsequent state was -2.29% and -R64 372 818.85 respectively.

Opsomming

Droëland boerdery stelsels in die Suid-Kaap maak grootliks staat op eksterne insette om in ŉ finansieel haalbare manier te funksioneer. Gedurende die afgelope jare het die prys van sleutel boerdery insette toenemende finansiële druk op boerdery stelsels in die Sui-Kaap geplaas. ŉ Proef is onlangs begin in die Suid-Kaap om grond regenerasie te assesseer asook die impak daarvan op toekomstige gewas en lewendehawe produksie. Die proef is gebruik as vertrekpunt vir hierdie studie ten einde verskillende produksie scenario's te simuleer. Regenerasie landbou deel geselekteerde beginsels met ander boerdery praktyke soos bewaringsboerdery, meer fokus op die die mimiek van die biologiese komponent bo eksterne insette. Die doel van die studie is om ondersoekende navorsing toe te pas op die finansiële implikasies van toekomstige regenererende boerdery praktyke in die Suid-Kaap. ŉ voorgestelde resultaat van die langtermyn implementering van regenererende boerdery praktyke in die Suid-Kaap is die vestiging van van landbou praktyke wat goed aangepas is om die impak van veranderende weersomstandighede en skadelike praktyke te oorkom.

Die ondersoekende aard van die studie is ideaal vir die gebruik van simulasie modellering waar hipotetiese veranderinge aangebring kan word aan ŉ tipiese bewaringsboerdery stelsels wat tans in die Westelike Rûens gebruik word om insig te verkry aangaande die moontlikhede van die implementering van suiwer regenererende boerdery praktyke. ŉ Multidissiplinêre groepbespreking is gehou om ekspert kennis te inkorporeer in moontlike produksie scenario's aangaande suiwer regeneratiewe boerdery praktyke. Die konsep van tipiese boerdery is toegepas as teoretiese hulpmiddel ten einde die verskillende produksie scenario's te simuleer wat produsente van bewaringsboerdery stelsels in die Westelike Rûens mag uitdaag indien hulle omskakel na suiwer regeneratiewe stelsels en praktyke. ŉ Geheel plaas multi-periode begrotings model is opgerig baseer op inligting ingesamel via plaaslike agribesighede, gedurende die groepbesprekings en deur verskeie direkte mededelings. Die netto huidige waarde (NHW) en die interne opbrengskoers op kapitaal investering (IOK) is die maatstawwe van geheel plaas winsgewendheid vir die relevante finansiële assesserings.

Vier scenario's baseer op regeneratiewe beginsels is geassesseer na gelang van finansiële implikasies soos gemeet aan die NHW en die IOK vir die tipiese plaas. Scenario beplanning is toegepas om die verskillende veranderinge op die aanvanklike status van die plaas te assesseer as ŉ persentasie verandering op NHW en IOK op die gevolglike status. Die aanvanklike status van die tipiese boerdery wys ŉ IOK van -3.22% en NHW van -R66 405 812.70. ŉ Jaarlikse afname van 10% in die hoeveelheid anorganiese stikstof kunsmis, ŉ drakrag van 5.5 kleinvee eenhede/ha en ŉ voedingsglyskaal van die gewas/weiding stelsels

na 70/30 was die mees winsgewende veradnringe wat aangebring kon word op die tipiese plaas oor 'n 20 jaar periode. Die geakkumuleerde effek van die veranderinge wys 'n positiewe effek op die verwagte geheel plaas winsgewendheid. Die IOK en die NHW vir die tipiese plaas in die gevolg toestand was onderskeidelik -2.29% en -R64 372 818.85.

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List of Abbreviations

ROA: Regenerative Organic Alliance

FMD: Foot and Mouth Disease

Ha: Hectares

T (t): Tons

Kg: Kilograms

N: Nitrogen

CA: Conservation Agriculture

IRR: Internal Rate of Return on capital

NPV: Net Present Value

LEI: Low-External Input (LEI)

IEI: Intermediate-External Input

HEI: High-External Input

GMO: Genetically Modified Organisms

WACC: Weighted Average Cost of Capital

GPV: Gross Production Value

SOC: Soil Organic Carbon

SOM: Soil Organic Matter

Lbs: Pounds

A (a): Acres

Yr (yr): Years

FST: Farming Systems Trial

Chapter 1: Introduction

1. Background

The impact of climate change on commercial agriculture is widely documented (Vermeulen *et al.,* 2012; Johnston *et al.,* 2013 and Calzadilla *et al.,* 2014). Over time climate change altered the efficiency of global agricultural production, which makes it important for farming systems to remain progressive and dynamic in adapting to stressors within the farming environment (Wilk *et al,* 2013). Farmers are faced with complex issues such as rising input costs, less predictable climatic conditions and the indirect impact of negative externalities associated with commercial agriculture (Lal, 2004 and BFAP, 2019). These issues are largely autonomous to individual farmers and can vary in intensity between countries. The ability of the agricultural value chain to address the absence of globally uniform institutional support for developing regions will grow in stature as the level of cohesion between farmers, policy makers and key related institutions improves.

The lack of free-flowing synergy between commercial farming practises and the natural environment are at the forefront of the underlying problem addressed in this study. This growing lack of synergy is becoming increasingly evident in regions where the relentless repetition of less optimal farming methods has left large spaces of arable land exposed and subsequently unproductive. As a result, the havoc wreaked by increasingly irregular natural phenomena, such as droughts, floods and fires, are leaving the natural environment defenceless and unable to regenerate itself at an equivalent or faster rate than degradation.

The cereal crop producing community of the Western Cape have made positive strides with the implementation of a wide variety of sustainable agricultural practises (Kuschke *et al.,* 2019). In 2019, a trial was initiated by the Western Cape government to assess the possibilities regarding soil regeneration and the subsequent impact thereof on crop and animal production in the Southern Cape. The implementation of this trial at Tygerhoek Research Farm (near Riviersonderend) opened a door of opportunity to research the applicability of purely regenerative farming practices in a meaningful way in the Southern Cape. The financial implications of regenerative agriculture in the Southern Cape have not yet been assessed. This study assessed the financial implications of regenerative agriculture in the Southern Cape and the subsequent impact on future animal and winter cereal crop production.

1.1. Problem statement and research question

According to Stats SA (2020), 46% of activities conducted by agricultural entities in the Theewaterskloof municipal area are solely crop related, 29% animal related and 18% under mixed farming systems. Regenerative practises can be used as a vehicle to increase the number of mixed farming systems in this area by integrating and stacking farm enterprises while simultaneously rejuvenating eroded and potentially nutrient deficient soils. The anticipated result of these practices over time is the emergence of natural drought resistant traits within Southern Cape farming systems.

The main research question was: what are the financial implications for possible future regenerative farming practices in the Southern Cape? A proposed result of the long-term implementation of regenerative farming practices is the formation of agricultural practises that are well adapted to inherently internalise the impact of changing weather patterns and harmful farming practises in the Southern Cape. Empirically, this could be achieved on a farm level by reducing the need for artificial inputs and thus creating room for increased whole-farm profitability. This study was area specific and related to the ongoing soil regeneration trial, which could potentially help industry stakeholders to assess the financial implications of integrating purely regenerative practises into their current farming systems.

1.2. Objective and hypothesis

The aim of the research is to evaluate the financial implications of future regenerative farming practices in the Southern Cape. To ensure the central aim the following goals are set:

- To describe the practical characteristics of implementing regenerative farming principles in Southern Cape production systems.
- To evaluate the expected financial implications of converting to regenerative farming principles.
- To differentiate regenerative farming from other farming orientations aimed at sustainable farming.

1.3. Data and research approach

A suitable simulation model was developed for a typical farm in the Western Rûens[1] using inputs from local farmers and experts in the Southern Cape region. The typical farm simulated in this study could have the potential to contribute knowledge to future research and local

[1] The Rûens is a relatively homogenous farming area within the Overberg situated between the Caledon, Swellendam, Heidelberg and Bredasdorp districts (Louw, 1989).

industry stakeholders to build on the financial implications of regenerative farming on future crop and livestock production in the Southern Cape. Budget models can be simulated to incorporate a whole-farm approach in a risk neutral decision-making environment. Conceptually farmers would be able to simulate their farming systems using the model constructed to interactively test various potential production outcomes of regenerative farming practices. The purpose of this study is not to accurately define the financial impact of regenerative farming but rather to apply an explorative approach to simulating the financial implications of the changes that a typical farming system under CA in the Southern Cape might undergo when adopting selected purely regenerative practices.

To assess the financial implications of purely regenerative systems in the Southern Cape, data was collected in the form of direct communication, written communication and a multidisciplinary group discussion. The data collected was used to construct a whole-farm multi-period budget model. The budget model was structured to initially follow a whole-farm approach using conservation agriculture principles and subsequently regenerative principles. By adhering to these principles, the simulation model built can serve as a foundation and framework for future research on the financial implications of regenerative farming practices in the Western Rûens. Local farmers and experts were consulted during the development of model assumptions and the overall structure of the simulated systems. In Chapter 2, the details and context of regenerative farming are discussed.

Due to the absence of a meaningful data set and regenerative agriculture not yet being formally researched within the context of Southern Cape farming systems, the research conducted in this project will be exploratory (Saunders *et al.,* 2016). An explorative approach will enhance the scope of this study as the research conducted will initially be broad in Chapter 2 and gradually be more focused as the study develops in Chapter’s 3 and 4. This approach will allow the development phase of the simulation model to remain flexible and interactive throughout the study to accommodate changes encountered during data interpretation and collection (Saunders *et al.,* 2016).

The budget model simulated in this study is created to explore production scenarios over a period of 20 years. The length of time chosen to base a forecast on can vary between budget models simulated, depending on the nature of the study in question. The typical farm simulated in this study exists within the biological and financial parameters of the Western Rûens homogenous farming area. To measure the changes required to alter a CA farming system to a purely regenerative farming system, the current financial position of a typical farm managed according to CA principles was established. The “initial” financial position of a typical farm was used as the basis from which to assess the financial implications of simulated changes to the system under regenerative principles in a “subsequent state”. As a relatively novel concept in Southern Cape farming systems, the possibilities for regenerative farming practices in the Western Rûens are numerous and carry significant levels of risk and uncertainty for the future of crop and animal production decisions. Scenario planning and typical farm theory are explorative research tools used to hypothetically assess a range of the most likely possibilities surrounding the financial impact of regenerative practices in the Western Rûens.

1.4. Outline of the study

This study consists of 5 chapters. Chapter 2 is a literature review, Chapter 3 the application of farming systems thinking to a typical farm in the Western Rûens, Chapter 4 the results and findings and Chapter 5 the conclusions, summary and recommendations.

In Chapter 2, the theoretical concepts surrounding the holistic approach of regenerative and systems thinking in an agricultural context are unpacked and applied to the notion of introducing purely regenerative farming practises to farming systems in the Southern Cape. This is achieved by organising existing literature into a logical sequence consisting of seven parts. Each part is aimed at reviewing the key aspects of regenerative agriculture and systems thinking.

In Chapter 3, some of the key concepts discussed in Chapter 2 will be applied to the farm level and explained according to the thought processes that underpin the financial assessment of regenerative agriculture in the Southern Cape. Chapter 3 consists of five sections regarding the geographical context of the study, typical farm theory, the structure of a whole-farm budget model and the applicability of scenario planning to this study.

Chapter 4 consists of two sections. In the first section, the final budget model used in this study will be explained in detail according to the assumptions, parameters and values validated during the group discussion. In the second section, various changes will be made to the typical farm simulated using scenario planning. The financial implications of purely regenerative farming practices on future crop and animal production in the Southern Cape will be assessed.

Chapter 2: Literature Review

2. Introduction

Chapter 1 introduced this study by contextualising and establishing the empirical need for additional research on regenerative farming systems in the Southern Cape. The purpose of this chapter is to unpack the theoretical concepts of the holistic approach to regenerative and systems thinking in an agricultural context and to apply it to the notion of introducing purely regenerative farming practises to Southern Cape farming systems.

This chapter consists of seven parts. Each reviews a key aspect of regenerative agriculture and systems thinking in a logical manner. The first part details the significance of crop and livestock farming in the Western Cape. Part two and three contextualises the progressive nature and value of regenerative farming and thinking in modern agriculture. Part four and five address the importance of a whole-farm systems approach to agriculture, the farm-decision making environment and modelling farming systems. The final two parts entail a discussion on the conceptual applicability of budgeting and the assessment of the financial implications of regenerative agriculture on future crop and livestock production in the Southern Cape, by a multidisciplinary group.

2.1. Crop and livestock production in the Western Cape

In recent years, periods of drought and rising input costs in the Western Cape have continued to put pressure on the factors ensuring profitability in crop and livestock production. The cumulative impacts of a series of unfavourable events such as a lack of political stability, economic performance and overall investor confidence in recent years had on the stability of the Rand, resulted in the higher import prices of inputs. Changes in Brent Crude oil prices had a similar impact on fuel and fertilizer cost structures which rapidly filters down to a farm level where farm activities and the market prices of agricultural inputs are affected (BFAP, 2020).

The Western Cape is well known for its rich biodiversity and area specific climatic conditions that created a favourable environment for the production of a variety of agricultural commodities (Pool-Stanvliet *et al.,* 2017). From an economic perspective, the Western Cape makes an important contribution to the South African agricultural sector. Various high value irrigated fruits such as grapes, citrus, stone fruits and pome fruits are produced in the province and exported to foreign countries (Kuschke, 2020). In the lower lying areas of the Western Cape, fertile soils combined with wet winters and hot, dry summers form a suitable farming environment for the dryland crop production of winter cereal grains and livestock. Farmers in these areas often combine dryland crop and livestock production activities to create complementarity and diverse activities within their farming systems.

2.1.1. Winter cereal crop production

The Swartland and the Overberg Rûens (Annexure AAnnexure A: Small grain production areas in the winter rainfall region of the Western Cape.) in the Western Cape is part of a small percentage of land in South Africa suitable for rainfed or dryland cropping and are therefore key production regions for winter cereals (Kuschke, 2020). Originating from shale and granite rock, the soils of these two fertile areas support the production of key crops such as wheat, barley and canola (Pool-Stanvliet *et al.,* 2017). To a lesser extent, plants such as oats and lupines are also grown in the Swartland and the Overberg Rûens to enhance the effectiveness of crop rotation systems.

2.1.1.1. Wheat

South Africa is a net importer of wheat and only about half of the domestic demand is met by local production (BFAP, 2020). Approximately 540 000 ha of wheat were planted nationally in the 2019 season of which 60% was planted the Western Cape (DAFF, 2019).

BFAP (2020) anticipates a 38% increase in wheat yield by 2029, relative to the 2017/19 base period. This increase will likely occur as a result of technological gains resulting in higher wheat yields per hectare. The above-mentioned issues of drought and rising input costs had a negative impact on the expected wheat production for the end of 2019 with an average yield of 3.14 t/ha and approximately 1.7 million tons, which is significantly lower than the 5-year average of 3.34 t/ha. On a farm level hard wheat[2] cultivars in the Western Cape are usually planted between April and June and harvested from October to December (DAFF, 2019).

2.1.1.2. Barley

Annual rainfall and growing conditions are important factors in barley production and can have a significant impact on crop yield and quality. In South Africa, the Southern Cape is one of the few geographic areas where producing rainfed malting barley is financially feasible. A large part of the malting barley grown in South Africa is used for brewing beer and the remainder for livestock feed and pearl barley (DAFF, 2019). The geographic suitability for barley production in the Southern Cape has facilitated various cost advantages for the small grain

[2] Harder cultivars of wheat are usually used for baking bread and softer wheat cultivars for confectionaries (DAFF, 2019).

industry regarding transport to storage facilities and research efforts. In 2019, 92% (122 000 ha) of the malting barley planted in South Africa was within the Western Cape with the estimated production in the province 364 860 tons (DAFF, 2019).

The market for malting barley in South Africa is centred in a company called ABinBev who procure a large volume of the crop produced domestically. Barley farmers in the Southern Cape are typically offered fixed-price forward contracts ahead of the planting period. The price of malting barley is competitive in relation to the price of wheat which is an alternative commodity for barley producers to grow. South Africa will likely become self-sufficient in malting barley production within the next decade as the capacity utilisation issues resulting from the national COVID-19 lockdown are resolved (BFAP, 2020).

2.1.1.3. Canola

The canola plant produces an oil seed that can be crushed to produce a high-quality oil for household use and as a source of protein in animal feed mixes. A large share of the canola crop in South Africa is grown in the Southern Cape. Canola is expected to follow a similar growth trend in yield compared to wheat, heading towards 2029, with a 35% increase (BFAP, 2020). This increase will likely be due to improved cultivars being established that are inherently resistant to certain herbicides and increased use in crop rotation systems. Canola has been shown to have a positive impact on yield, root penetration, soil water retention, disease and pest control and soil cover for subsequent crops such as wheat (DAFF, 2019). In the 2018/19 season, enough canola was produced domestically at 112 110 tons (excluding carry-out stock) to meet the quantity demanded of 110 540 tons. Producer prices vary according to the protein content of the canola seeds and whether the end use of the produce is for animal or human consumption.

2.1.2. Livestock production

In the Western Cape, residual crop material from harvested winter cereal crops is often used as grazing for sheep and cattle during the summer months. By creating complementary forward and backward linkages between crop and livestock enterprises, crop farmers in the Swartland and Overberg Rûens are able to improve their whole-farm cash flow with the production of commodities such as wool and mutton. External shocks such as exchange rates, foot and mouth disease (FMD) outbreaks and drought can affect the market price and thus profitability of livestock production. In recent years, meat and wool production have been affected by each of these exogenous shocks which has made farming livestock challenging and put farming businesses under considerable pressure (BFAP, 2020).

2.1.2.1. Mutton

Merino sheep farming is a practice well suited to the farming conditions in the more arid regions of South Africa. While there are various breeds of sheep farmed in the country, Merinos are the most popular in dryland farming as they are well adapted to produce high-quality meat and wool considering the arid conditions (Tainton *et al.,* 1987). Relative to pork and chicken, mutton is an expensive meat and demand can be influenced by changes in consumer buying power. In addition to price, issues such as predation, disease, stock theft and drought tend to have an adverse effect on the domestic mutton market. Large quantities of mutton carcasses and cuts (fresh or frozen) are exported to countries such as the United Arab Emirates, Lesotho and Saint Helena. Imported mutton carcasses and cuts (fresh or frozen) are imported from countries such as Namibia and Australia (ITC, 2020).

The Western Cape makes an important contribution to production, with the fourth largest number of sheep on a provincial level, for domestic supply and exports at 12% (DAFF, 2019). The sheep industry in this province has various geographical advantages in the mutton value chain with an export point in the City of Cape Town Metropolitan Municipality and the key mutton production areas in close proximity.

2.1.2.2. Wool

Wool production in South Africa consists mostly of Merino wool destined for the apparel industry where finer microns are preferred. China is a major importer of South African wool, typically procured in either a semi-processed or greasy form. The wool market has faced significant challenges in recent years amid periods of drought, export delays as a result of FMD and the global impact of the COVID-19 pandemic (BFAP, 2020). Future wool production is forecasted to grow amidst increasing consumer and buyer confidence surrounding adherence to best industry practice certifications on a farm level and during textile processing.

From a production perspective, the Western Cape produced the third largest volume of wool at 18.1% or 8 248 451 kg in the 2018/19 season (DAFF, 2019). In the 2019/20 season, Bredasdorp and Caledon in the Overberg Rûens were ranked as the top two areas under winter rainfall wool production at 1 336 072kg and 1 236 430kg respectively (Cape Wools SA, 2020a).

Sheep are usually shorn every 8 months (or longer) to ensure a financially feasible length of clean wool to grow. However, sheep can be shorn at any stage as long as there is enough wool to shear. The price of wool can vary greatly between auctions and can often be impacted by external shocks or exchange rates (DAFF, 2019). Wool auctions are coordinated by the South African Wool Exchange and take place on a weekly basis between August and June. Wool auction prices make an important economic contribution to South African agriculture through earning foreign currency.

2.2. Regenerative farming systems

Regenerative agriculture is a relatively new concept in South African agriculture which eagerly awaits a formal definition. The purpose of this section is not to formally define regenerative agriculture in the context of South African agriculture, but merely to describe the broad set of principles and suggested practices outlined in existing literature (both formal and informal) by international institutions, scientific studies, researchers and farmers[3].

Additionally, the ideal combination of regenerative farming practises depends on geographically specific information such as the type of farming, climatic conditions and soil health. This section will attempt to give a broad definition of regenerative agriculture within these parameters and with reference to the trial that this study is based on.

2.2.1. Broad definition

Robert Rodale initiated the term "regenerative organic[4] agriculture" to announce the arrival of a novel "ground-up" approach to the design of farming systems (Rodale, 1983). Conceptually, regenerative organic agriculture consists of a set of farming principles that are structured to closely mimic biological processes and nutrient cycles to create a balanced relationship between agriculture and nature (Rodale Institute, 2020a). Enhancing resources on a farm level may include; increasing biodiversity through intercropping, moving away from annual plants to perennials and relying on internally produced resources as far as possible (Rodale Institute, 2014). A farming system that is inherently regenerative utilises biomimicry to shape farm management practices that improve soil health and subsequently rejuvenate natural soil functions (Pretorius, 2020). According to Pretorius (2020), a regenerative farming system with the intent to improve soil health should incorporate six management principles. In Figure 2.1, these six principles are illustrated as components of a whole farming system that work in unison toward the formation of a more holistic and regenerative management style.

[3] For example: Dahlberg, 1994; Lacanne *et al.*, 2018; Oakland Institute *et al.*, 2015; Pearson, 2007; Rhodes, 2012, 2015, 2017; WWF, 2019; Rodale Institute, 2011, 2014 and Rodale, 1983.
[4] The use of the word "organic" in this phrase likely alludes to the fact that regenerative processes can be called organic but not vice versa (Rhodes, 2015).

Regenerative agriculture shares selected foundational principles with other farming practices such as conservation agriculture (CA) but puts a greater emphasis on biomimicry than external inputs. The first three principles of regenerative agriculture indicated in Figure 2.1; no or minimal soil disturbance, soil cover and plant diversity, are common CA principles but the remaining principles focus on internal inputs in the form of biomimicry and soil function. Regenerative farming systems typically include one or more animal types, the maintenance of living roots in the soil during the year and ensuring that the cropping system implemented improves soil health in the long term (Pretorius, 2020).

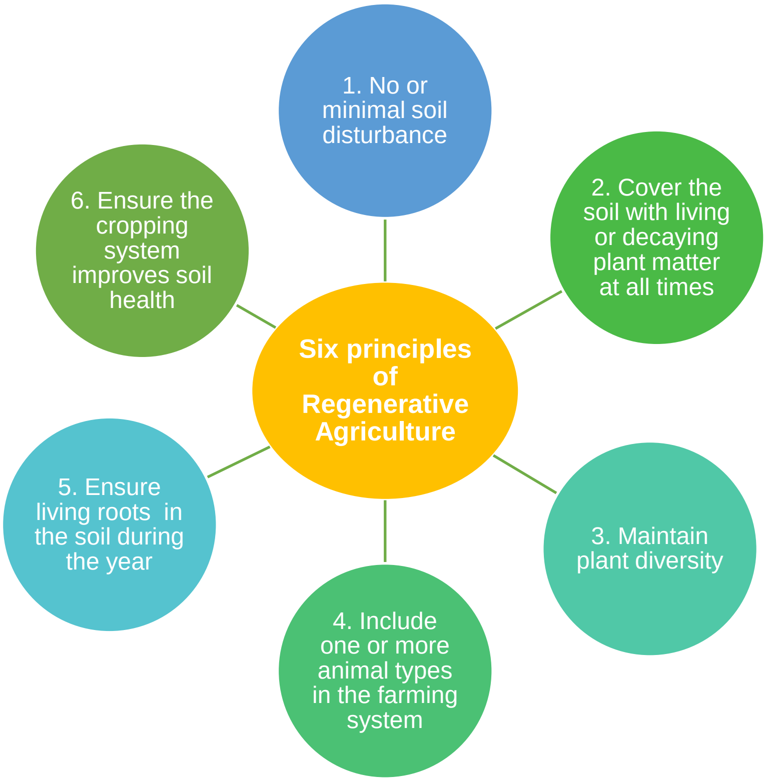

Figure 2.1 - Six key principles of regenerative agriculture. Source: Pretorius (2020).

Regenerative farming practices implemented under these principles often involve the stacking of enterprises to attain a balance between mimicking biological processes and maintaining whole-farm profitability. Complementary enterprises are often combined to create and maintain a mutually beneficial nutrient cycle for each aspect of the business to benefit. An example of such a cycle is the planting of mixed grazing cover crops in a field that are initially grazed by cattle and then smaller animals such as pigs, sheep and chickens. Each of these animals play a role in the cycling of nutrients, farm cash flow and the preparation of the field for cash crops such as barley, wheat or canola to subsequently be planted.

Various broad definitions exist for regenerative agriculture which differ based on the vision of the institution in question. Each of the practices mentioned in this broad definition are well positioned to aid in the design of climate resilient food production systems that could aid in global food sovereignty and agro-ecologically based farming systems. The Carbon Underground (2017) provide a simple and clear broad definition of regenerative agriculture that, in essence, represents the context of this study:

"*a holistic land management practice that leverages the power of photosynthesis in plants to close the carbon cycle, and build soil health, crop resilience and nutrient density*."

Research on regenerative farming systems is currently underway in the Western Cape at a research farm called Tygerhoek. The research being conducted is focused on soil regeneration and could potentially narrow down the broad definition given above to a farm-level in the Rûens homogenous farming area[5]. The regenerative practices being trialled include:

- *Integrated crop rotation systems* – Cash crops are rotated with a mix of legumes and nitrogen fixing cover crops to act as a natural fertilizer, reduce soil disturbance, allow carbon sequestration and as a result, replenish soil nutrient and water cycles.
- *Pollinator strips* – The planting of a mixture of self-seeding perennial flowers on the edge of crop fields could enhance the presence of beneficial insects for pest control, pollination and a reduced need for soil disturbance. Bees will also be introduced next to the pollinator strips to provide crop and flower pollination services and for subsequent honey production.
- *Crop/livestock integration* – A mixed farming system will facilitate the stacking of enterprises and allow for mutually beneficial processes to increase biodiversity and crop yields. For example, animals will graze on cover crops in a manner consistent with holistic land management practices[6] to encourage future biological processes and to serve as feed for the livestock.
- *Zero-till* – No soil tillage will be conducted and only minimal soil disturbance will be used for planting (zero-till disc seeder or low disturbance no-till) and the termination of cover crops with rolling and crimping.

[5] The Rûens homogenous farming area will be discussed in greater detail in Section 3.1.1.
[6] The purpose of holistic land management practices will be explained in Section 2.2.4.2.

- *Biochar* - Biochar is used in the trial to serve as an environmentally friendly alternative to synthetic fertilizers. Biochar can assist in increasing soil organic matter, carbon sequestration and plant growth (Oldfield *et al.*, 2018).

These practices have been carefully selected and integrated into the trial site to provide cash crop farmers in the Rûens homogenous farming area with a tool to offset the mounting pressure imposed by high input prices, unpredictable climatic conditions and low commodity prices on whole-farm profitability. With future research, the broad definition of regenerative agriculture in the Rûens homogenous farming area given above, can be improved upon and possibly expanded to other farming areas in the Western Cape.

2.2.2. Differentiating regenerative, sustainable and organic agriculture

Sustainable farming systems in South Africa employ similar practices to regenerative agriculture but differ in some instances. Firstly, sustainable farming practices are structured to maintain and preserve soil and other scarce resources while regenerative agriculture is structured to rebuild soil structures. Secondly, sustainable farming practices such as conservation agriculture share no-till, crop rotation and mulching with regenerative agriculture but have no restriction on the use of synthetic inputs or GMO seed[7] (Buchner *et al.,* 2011). In short, regenerative agriculture follows the directive of rebuilding lost resources rather than sustainably depleting them.

Rhodes (2015) differentiates between organic and regenerative agriculture on the simple premise that all regenerative processes can be labelled organic but not *vice versa*. Regenerative farming systems employ a full life cycle approach to intensify the essence of sustainable agriculture by maintaining and reproducing scarce resources that have been lost (Rodale Institute, 2020; Rhodes, 2015).

2.2.3. Potential benefits and limitations of regenerative farming systems

As South African agriculture continues to grapple with historic land issues, insufficient governmental support and equitable policy, farming systems involving regenerative practises may become an increasingly attractive interim and long-term solution. Agro-ecologically based farming systems such as regenerative agriculture tend to be more knowledge intensive than capital intensive which could pave the road for effective and well placed farm-level extensive services and farmer support programmes (Aliber *et al.*, 2012 and Holt-Giménez *et al.*, 2013).

[7] GMO seeds are not used in the Western Cape (Strauss, 2020a).

Furthermore, the widespread adoption of an agro-ecological based farming system such as regenerative agriculture could help reduce the ecological footprint of modern agriculture by regenerating soils that were previously void of various nutrients (Rhodes, 2012). With improved soils, farmers following regenerative farming practices could in the long-term start seeing increases in net profit margins due to independence from expensive fossil fuel-based inputs (Lacanne *et al.,* 2018).

During periods of drought or financial strife cash flow can financially make or break a farming business. The conversion of a farming system from conventional or sustainable agriculture to regenerative agriculture takes time and cannot be rushed beyond biological limits without breaching regenerative principles and using synthetic inputs. During this transition period, farmers may experience decreased yields and net profit due to reduced synthetic inputs used to supplement dehydrating nutrient cycles (Strauss, 2020b). Biologically based barriers used to counteract issues of poor plant growth, pest or weed issues require highly accurate information on agro-ecological systems that need to be designed on a farm specific basis.

The current farming environment for crop and livestock farmers in the Southern Cape may raise a few concerns for the introduction of an alternative farming system such as regenerative agriculture. Firstly, Southern Cape farmers may already be implementing conservational farming systems that inherently employ cover crops and many farmers may lack clarity on the difference between the two practices. As a rainfed cropping area, inconsistent weather patterns increase the level of uncertainty for the farmer, creating a decision-making environment which in turn diminishes a farmer's appetite for the risks associated with the adoption of new farming systems (Strauss, 2020a). Farming systems currently applying conservation agriculture in the Southern Cape are well positioned to fully emerge from medium-low efficiency systems to high efficiency systems (Figure 2.8).

2.2.4. International research on regenerative agriculture

Regenerative agriculture is successfully implemented in various parts of the world and supported by numerous farmers, researchers and institutions[8]. A significant amount of research has been conducted on sustainable agricultural practices that incorporate some regenerative practices, such as soil health, but few (Lacanne *et al.,* 2018) have assessed the financial implications of purely regenerative farming practices.

[8] References were given in Footnote 3.

Lacanne *et al.,* (2018) conducted a study on corn production in the Northern Plains of the USA. The study assessed the effectiveness of regenerative and conventional practices on pest management, soil conservation, productivity and farm profitability. The regenerative and conventional farms were defined according to best-management practices employed by farmers in the study group. It was found that the regenerative system not only enhanced the agro-ecological interactions on the farm but was also more profitable. With regards to pest management, the number of pests in pesticide treated corn fields in the conventional system was significantly higher than in the regenerative system (Figure 2.2). Figure 2.3 represents the revenue and cost per hectare, on average, of all the fields in the study.

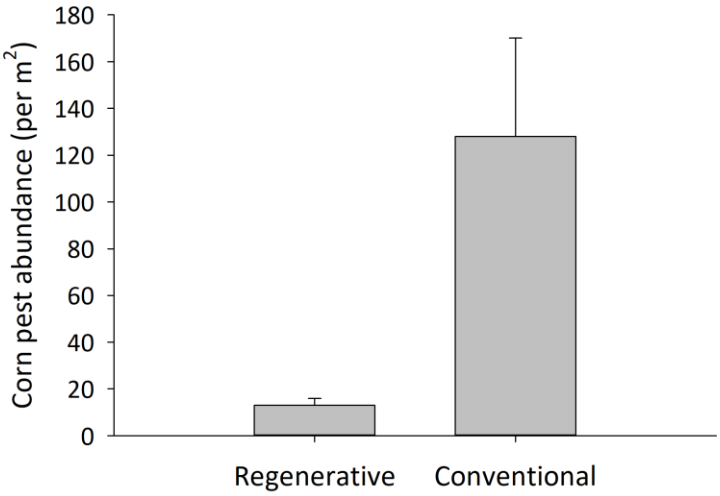

Figure 2.2 - Pest abundance in regenerative and conventional corn fields. Source: Lacanne et al., (2018).

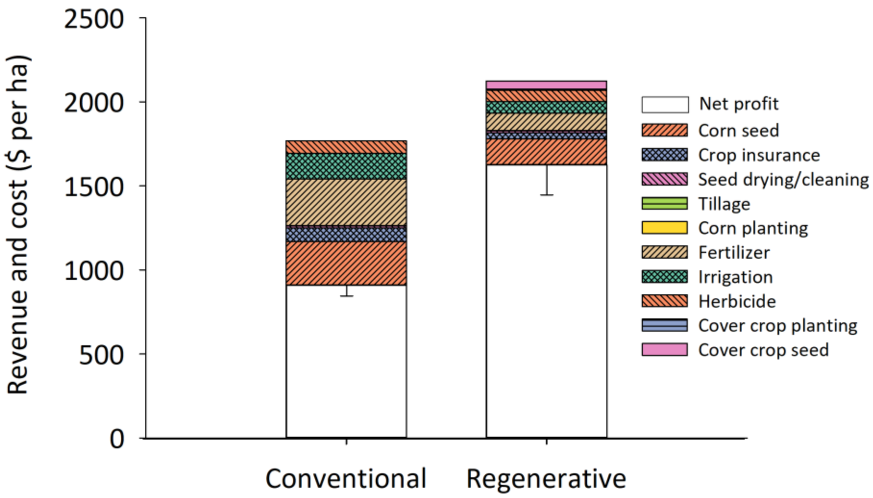

Figure 2.3 - Revenue and cost of conventional and regenerative corn fields. Source: Lacanne et al., (2018).

It was found that the regenerative system had a 70% higher profit than the conventional fields. According to Lacanne *et al.,* (2018), the profit made in the regenerative system was not as a result of higher yields, but was correlated to the particulate organic matter of the soil. Figure 2.4 indicates this trend as the corn fields that had higher soil organic matter and a lower bulk density were more profitable. Lacanne *et al.,* (2018) conclude that by implementing localised regenerative farming practices, the farmers involved in the study required less inorganic inputs and had less pest control issues.

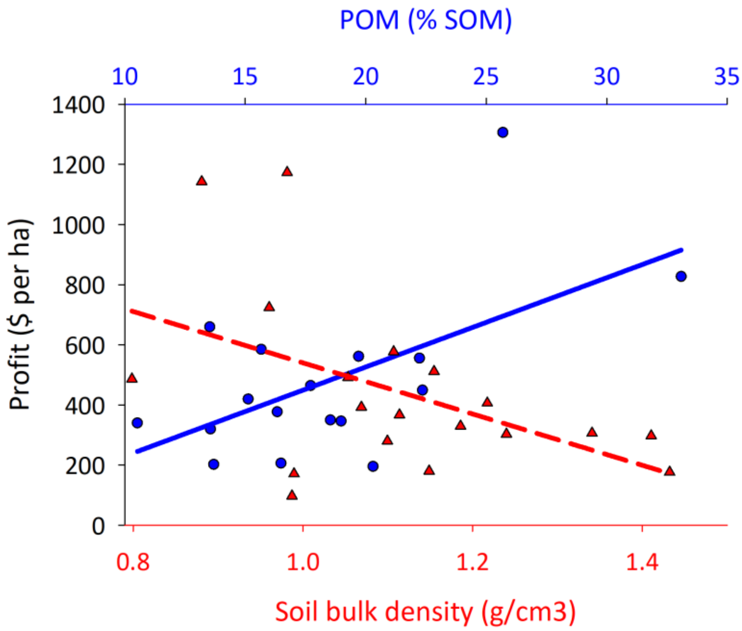

Figure 2.4 - Profit ($) per ha of soil bulk density (g/cm^3). Source: Lacanne et al., (2018).

2.2.4.1. The Rodale Institute

The Rodale Institute has contributed significantly to the research field of regenerative agriculture with ongoing multidisciplinary scientific research and on-farm trials over the past four decades. (Rodale Institute, 2011). A research program called the Farming Systems Trial (FST) is conducted on an ongoing research site in Kutztown (Pennsylvania). The Rodale Institute uses this program to collect data for USA grain farmers transitioning from conventional to organic farming. The trial consists of 72 plots, run under three broad systems: organic manure, organic legume and conventional fertilisation. The trials have measured the impacts of these systems on soil health, crop yields, energy consumption, water quality and crop nutrient densities. By conducting long-term trials the above mentioned data could be collected during natural cycles of drought and good rain to improve the reliability of the data.

The results of this long-term trial involving organic agriculture are relevant to regenerative agriculture as described in Section 2.2.2. Figure 2.5 illustrates the results of the FST after 30 years. Organic agriculture outperformed conventional agriculture on key indicators that are also applicable to regenerative agriculture. The yields of the organic system were more than equal to the conventional system (lbs/a/yr), more profitable per acre (annually), had lower energy inputs per year and lower greenhouse gas emission. Other relevant results of the trial were a 40% higher grain yield during droughts and no leaching of toxic chemicals into the water system (Rodale Institute, 2020b).

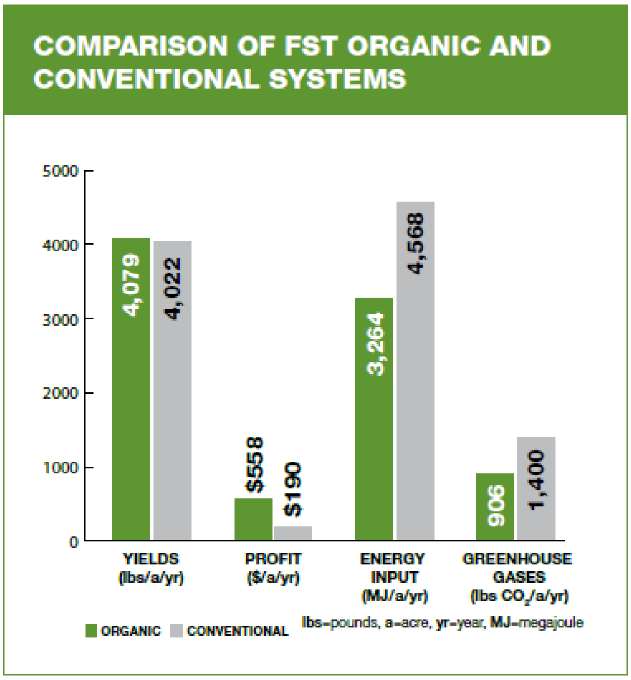

Figure 2.5 - Yield, profit, energy input and greenhouse gas comparisons between organic and conventional agriculture under the Farming Systems Trial. Source: Rodale Institute (2011).

In 1987, the Rodale Institute's Regenerative Agriculture Research Centre (RARC) initiated a program to help farmers restore their eroding soils and degraded land in central Senegal's groundnut basin (Oakland Institute *et al.* 2015). With the continued application of regenerative principles and continued agro-ecological knowledge inputs from the Rodale Institute, more than 10 000 farmers were trained and able to be less dependent on expensive inputs and farm on significantly improved soil by 2006 (Oakland Institute *et al.* 2015).

In 2018, the Rodale Institute initiated a non-profit organisation called the Regenerative Organic Alliance (ROA) to encourage and endorse regenerative agriculture through creating a certified standard to guide regenerative practises. The ROA consists of agricultural experts who specialise in farming systems, soil, animals and labour. The certification standard is based on the USDA[9] organic standards and regenerative farming practices. The certification standard was established in the form of a framework (Regenerative Organic Alliance, 2019a) and participant handbook (Regenerative Organic Alliance, 2019b) to unify existing approaches and practices to regenerative agriculture under three pillars. The first pillar, soil health, encourages conservation tillage, holistic grazing and the use of cover crops to increase soil organic matter and to sequester carbon. The second pillar is animal welfare. This pillar focuses on the humane treatment of animals and promoting a good quality of life. The third and final pillar is social fairness. Farmers are encouraged to facilitate good working conditions, enter into long-term commitments and compensate workers fairly under this pillar (Regenerative Organic Alliance, 2019b).

2.2.4.2. The Savory Institute and holistically planned grazing

In response to human and animal suffering at the hands of desertification, Allan Savory founded the concept of holistic planned grazing and initiated the Savory Institute. The Savory Institute advocates a holistic approach to grassland management systems that in turn has a positive impact on soil, animals and people (Savory Institute, 2020). Holistic planned grazing is fundamentally a form of regenerative agriculture applicable to livestock where grazing patterns are designed to mimic the natural movement of wildlife. A grazing plan is derived for each grassland in question to effectively implement holistic management practices and principles (Savory Institute, 2010). Grazing plans are continually updated to positively benefit the ecological, environmental and social (human) aspects that the livestock interact with. With the correct application and widespread adoption of holistic management practices, better soil health can be achieved in grasslands which in turn facilitates drought resilience in livestock farming systems, reduced greenhouse gas emissions and food security for communities involved (Savory Institute, 2020).

The international research reviewed in this section is merely the tip of a growing iceberg of knowledge that has the potential to improve the ecological and financial footprint of modern agriculture in many aspects. Additionally, this research indicates that it can be financially feasible to farm with regenerative practices, albeit under certain circumstances. The financial implications of regenerative practices in the context of Southern Cape farming systems will be assessed in this study.

[9] United States Department of Agriculture

2.3. Regenerative thinking in agriculture

The phrase "regenerative thinking" is not often used in formal discussions on the design of agricultural systems. This phrase will likely become increasingly important in addressing issues in agricultural production related to climate change, the distribution of food and degraded agro-ecosystems as these areas of concern are arguably having an escalating impact on agricultural production. The role regenerative thinking plays in climate resilient food production, food sovereignty and agro-ecologically based farming systems has grown over time and will be discussed in Sections 2.3.2 and 2.3.3.

2.3.1. The progression of regenerative thinking in agriculture

Issues such as soil erosion in developing regions, global climate change and the finite nature of fossil fuel-based energy have become a predominant area of concern for the future of food production. Agricultural processes and activities have been shown to be a major contributor to each of these issues by escalating the emission of greenhouse gasses, increasing the loss of fertile topsoil and raising the demand for fossil fuel-based inputs. The continued contributions by agricultural activities are widely forecasted to have a multiplying effect on the social, economic and natural environments in future.

Under conventional farming practices, modern agriculture has flourished on a diverse diet of technologies that have emerged from periods of rapid technological advancement. Two periods of technological advancement in the 20^{th} century were key to the success of modern agriculture and the progression of regenerative thinking. The first is the Haber-Bosch process. This process facilitated radical improvements in food production using a gas synthesis process to convert methane into ammonia, which is a key ingredient in the production of synthetic fertilizers (Rhodes, 2017). Mechanisation, synthetic fertilizers and other inputs, drastically increased crop yields and subsequently global population growth. Achieving these results came at a great cost to the environment as large amounts of fossil fuel and natural gases are required to sustain the inputs, production and distribution of the synthetically enhanced fertilizer (FAO, 2012).

Over time, the effects of industrial-like agriculture on the environment were exposed in the form of degraded land and the rapid spread of crop disease throughout mono-cropping systems in Africa and Asia (Rhodes, 2017). In response to widespread movements that created awareness on the effects of increased mechanisation and synthetic fertilizers on soil health, water resources and ecosystem biodiversity, organic and sustainable agricultural practices began to emerge (Rhodes, 2017).

The second important period of technological development that allowed modern agriculture to flourish was the Green Revolution. The Green Revolution refers to the period between 1940 and 1960 where a scientist named Norman Borlaug, well known for having bred genetically uniform, high-yielding and disease resistant crop varieties of wheat, rice and maize in Mexico and later in India (FAO, 2011 and Rhodes, 2017). The subsequent exponential growth in crop production can be comprehended in terms of global agricultural indicators such as fertilizer consumption, cereal production, cereal yield and irrigated land area that are illustrated in Figure 2.6. The harvested land area (Figure 2.6) of global crop production did not grow exponentially but stayed relatively constant which indicated that the high yielding crop varieties were intensifying the outputs of crop production on each hectare of already productive land. The Green Revolution was an important milestone for modern agriculture as various barriers in crop production such as plant disease, infertile soil, pest infestations and varying low yielding seed varieties during crop production were significantly reduced (Murgai, 2001 and Rhodes, 2017).

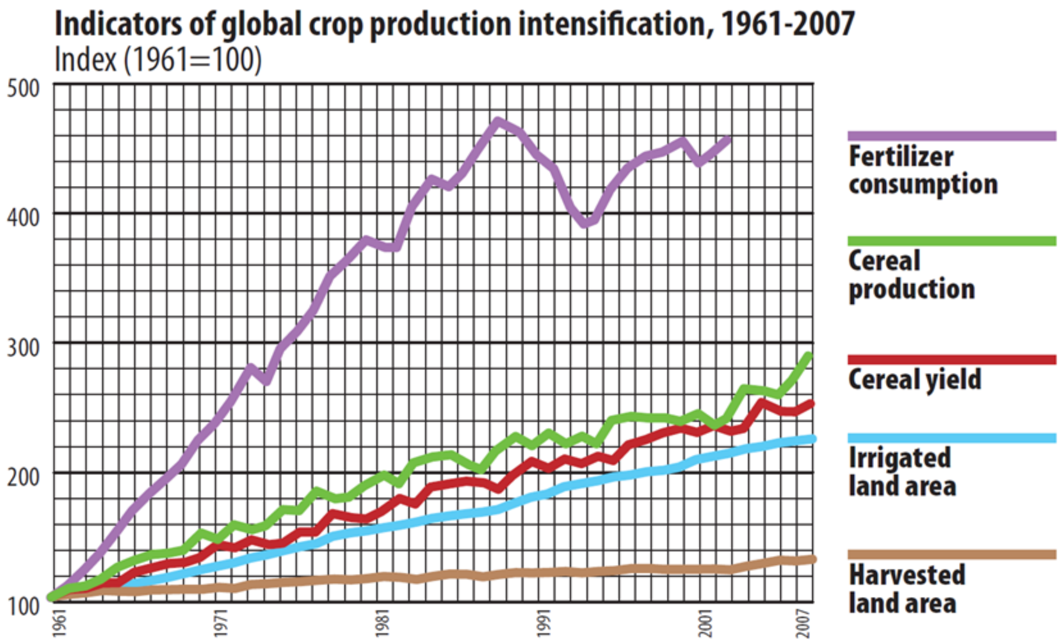

Figure 2.6 - Indicators of global crop production intensification from 1961-2007. Source: FAO (2011)

These two periods of technological advancement were important in curbing mass starvation and undernourishment but created a dependency on synthetic inputs in crop production that would become a major environmental issue in subsequent years (FAO, 2011). Additionally, the gradual loss in biodiversity in agro-ecosystems, instances of severely degraded soil, increased greenhouse gas emissions and polluted groundwater resources have become reality (FAO, 2012).

As the world's population continues to grow, current levels of food production will need to intensify. Considering the current environmental issues that are beginning to hamper crop production, future farming systems will need to endure a paradigm shift to incorporate regenerative thinking into the further intensification of modern agricultural systems. How this paradigm shift will take place in an economically and environmentally sound manner will take time and likely awaits a third period of rapid technological advancement. Until then, active research is required to expand the possibilities of alternative crop production methods to conventional modern farming practices.

Regenerative and sustainable agricultural practices share similar goals of attaining climate resilient food production, food sovereignty and agro-ecologically based food systems. The similarities of these systems require clarification on the boundaries of each system before attending to greater detail on the role regenerative agriculture plays in the realisation of these goals. The differentiation of farming systems according to their input levels is a valuable approach to be applied to this study as input costs are a big factor in crop and animal production in the Southern Cape.

The IISA/FAO (2010) differentiated crop types and production systems by classifying each system into one of three input levels, namely: low-external input (LEI), intermediate-external input (IEI) and high-external input (HEI) systems (Buchner *et al.*, 2011; FAO, 2012). Some farming systems require inputs at different stages during production, each of which may appear on either level of the input spectrum in Figure 2.7. HEI systems make up the bulk of modern agriculture and are designed to commercially optimise annual food crops using man-made inputs (such as fertilizers, fungicides and pesticides), monocultures and GMO's. As efficient as HEI systems are generating outputs, significant energy requirements throughout the food chain are necessary to uphold economies of scale (Buchner *et al.*, 2011). Farming systems such as mixed crop/livestock, conservation and organic agriculture often incorporate IEL systems. IEL systems tend to integrate improved crop varieties and some fertilizers and chemicals with agro-ecologically intensive knowledge. Energy use in these systems are increasingly efficient as there is less dependence on heavy mechanisation and increased reliance on agro-ecologically based practices such as crop rotation, the creation of mulch and no soil tillage (Buchner *et al.*, 2011). From an output perspective IEL systems are less market orientated than HEI systems as there is some subsistence production in addition to commercial sales (IISA/FAO, 2010).

LEI systems are typically used in farming practises such as regenerative agriculture, permaculture or organic agriculture where there is a strong focus on both resiliency and efficiency. Resiliency is achieved through low energy requirements and no chemical use which reduces the farms exposure to high input costs but does not reduce yields in the long term. Efficiency is attained in LEI systems through the creation of synergies between complementary enterprises for on-farm nutrient cycles and the use of perennial crop varieties that do not require heavy machinery (IISA/FAO, 2010; FAO, 2012).

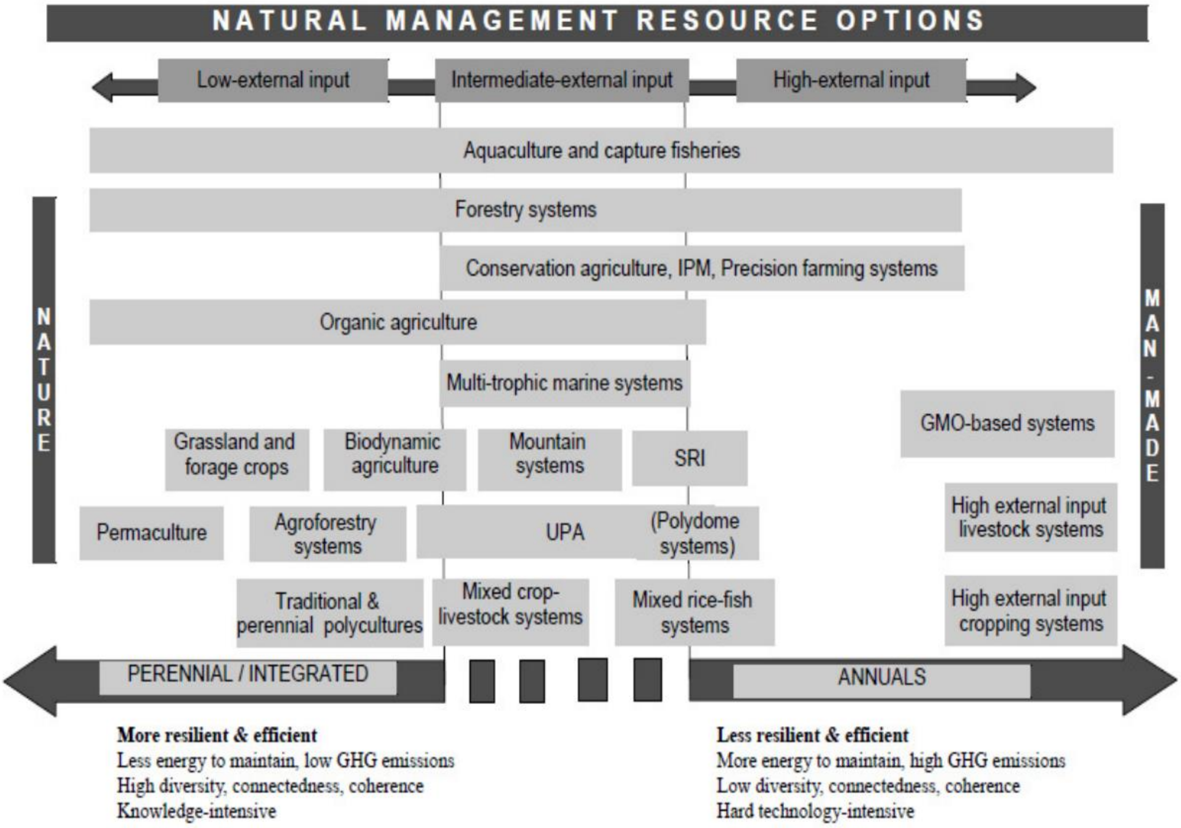

Figure 2.7 – Natural Management Resource options. Source: FAO/OECD (2011).

In summary, the emergence and progression of regenerative thinking will prove to be extremely valuable in the design of farming systems in future. The high dependency of commercial agriculture on synthetic inputs and volatile fossil fuel prices will soon lead global food production into acting on the opportunity cost between reducing inputs or facing an irreversible energy crisis (FAO, 2012). Going forward, the ability of modern agriculture to ensure enough resources for future generations will depend on finding a solution to environmental damage and non-regenerative resource use.

2.3.2. Agro-ecologically based farming systems

In the context of modern agriculture, an agro-ecological system opposes technologies that rose from the Green Revolution and resides with the more traditional management approach of ecosystems (Holt-Giménez *et al.,* 2013). Born out of necessity after the Green Revolution technologies depleted smallholder capital stocks. Agro-ecological farming systems developed over time to be commercially viable with the combination of indigenous knowledge and modern agro-ecologically orientated science (Holt-Giménez *et al.,* 2013). Agro-ecologically based farming systems follow a whole-farm approach by recognising (Rosset *et al.*, 1997): "*…the interrelatedness of all agroecosystem components and the complex dynamics of ecological processes*".

Population growth in developing regions and a diversifying dietary preference in developing regions such as Asia and Latin America are significant incentives for mixed farming practises. Agro-ecologically based farming systems provide a valuable foundation for diversified farming systems on both commercial and small scales (Thornton *et al.*, 2001). Figure 2.8 summarises the relationship between agro-ecosystem diversity and productivity. Farming systems such as regenerative and organic agriculture that require low amounts of external inputs, have high recycling rates and incorporate crop-livestock integration would have a high productivity and high agro-ecosystem diversity. At the other end of the scale, high input modern agricultural systems that employ heavy soil movement have a high productivity level and a low level of agroecosystem diversity, which renders it low in efficiency (Altieri et al., 2012; Funes-Monzote et al., 2009).

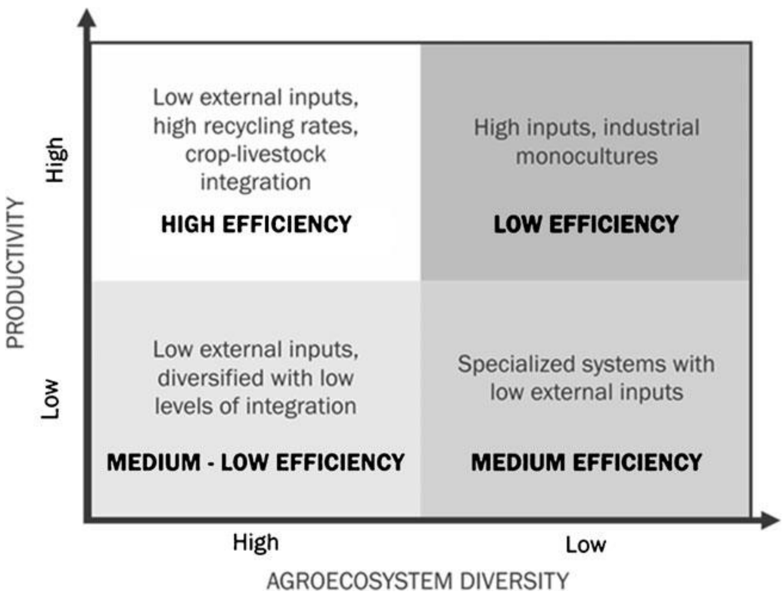

Figure 2.8 – The relationship between agroecosystem diversity and productivity. Source: Altieri et al. (2012) and Funes-Monzote *et al.* (2009)

2.3.2.1. Soil health

Good soil health is a key component in crop/livestock farming and without it a biologically cyclical environment cannot be formed aside from almost complete reliance on external inputs. Healthy soil typically contains both a variety of biota and large volumes of soil organic matter (FAO, 2011a; Dias *et al.,* 2014). Plants typically respond well to healthy soils and have a higher resistance to parasitic weeds. Furthermore, the more diverse the soil biota are, the greater the capacity of soil to conduct key processes for crop growth such as storing and releasing water or nutrients. Soil structure is therefore of great importance to plant growth as the ability of the plant roots to extend into the soil can be hampered by soil structures that have physical or chemical barriers that can arise from synthetic agricultural inputs or degradation (FAO, 2011a). Soil structures usually occur in a porous form and are based on the interaction between minerals, water and air (Rhodes, 2012). The pores in soil structures contain gas and liquids which influence life in the soil and the emission of greenhouse gasses.

An important indicator of soil health is the amount of soil organic matter (SOM) as it is closely linked to soil microbes, nutrient cycles and water retention capacity. SOM is typically measured according to the density of soil organic carbon (SOC), a gas naturally captivated within soil structures (Lehman *et al.,* 2015). Sustainable farming practices often include crop rotation systems and no soil movement to avoid breaking up soil structures and to increase SOC in the soil (Lehman *et al.,* 2015). Crop rotations involving small grains and legume cover crops, such as alfalfa and barley, have been proven to be efficient at increasing SOC and fixing nitrogen levels from the atmosphere in soil. Cover crop mixes containing nitrogen fixing legumes play an important role in soil health and the reduction of greenhouse gasses.

2.3.2.2. Cover crops and crop rotation

Crop rotation systems usually entail a combination of cover crops and cash crops that are grown either concurrently or interchangeably. Cover cropping involves the addition of high biomass producing crops (e.g. black oats, lucerne, black lentil or sweet clover) to crop rotation systems. High biomass producing crops aid in averting the repercussions of repeated agricultural issues such as soil erosion, inorganic chemical leaching, pest infestations, competitive weeds and decreasing year-on-year crop yields (Fageria *et al.*, 2005; Dias *et al.,* 2014). It is common practise for cover crops to be terminated with either herbicides (such as glyphosate) or mechanical methods (such as mowers or rollers/crimpers) before reaching maturity (Kornecki *et al.*, 2009; Fageria *et al.*, 2005).

2.3.2.3. Holistic grazing and livestock

Regenerative farming systems extend beyond crop production and can also be applied to livestock management to achieve similar whole-farm results. Crop-livestock farming systems are an integral part of the Tygerhoek soil regeneration trial as livestock are grazed in accordance with the holistic land management practices. On a practical level, holistic land management practices involve timed grazing, constant information feedback loops on animal impacts, holistic management of technology, human creativity and on-farm resources. Holistic planned grazing practices are based on four key principles (Savory Institute, 2010):

- “Nature functions in wholes”
- “Understand the environment you manage”
- “Livestock can improve land health”
- “Time is more important than numbers”

2.3.3. Climate resilient food production and food sovereignty

With the correct application, regenerative agriculture has the capacity to regenerate degraded soil structures and to provide a sustainable future for agricultural production. This practice is not limited to large-scale production farms and can be applied to small-scale farms as well. Africa is known for its vast amount of resource poor small-scale farmers in its developing countries. Regenerative practices can greatly improve the livelihoods of these farmers by enabling higher net profits and replenished natural resources for future production.

2.3.3.1. Climate resilient food production

South African food production systems are likely to be put under immense pressure in the near future. The WWF (2019) predicts that by 2050 there will be 10-17 million more South Africans and the average per capita income will increase by 150-200%. Such large increases in population size and income will require significant increases in agricultural output. For the food production system this means that the South African cropping system will need to increase in intensity and yield by up to 45% (WWF, 2019). Rising incomes in the middle- and upper-income brackets are causing a shift in the food types consumed. Furthermore, the demand for livestock and dairy products are expected to steadily increase towards 2050 based on current trends.

For centuries rainfed crop production has relied on seasonal rain and largely predictable climatic conditions. Increasingly irregular rainfall patterns and extended natural phenomena such as droughts and flooding require traditional farming systems to adapt accordingly (Beck, 2013). Figure 2.9 illustrates the change in average surface temperature and change in average precipitation between 1986-2005 and 2081-2100. The IPCC (2014) forecast that precipitation will intensify in certain regions of the world and that heat waves are more likely to occur and last for longer periods of time. With the average surface temperature of the earth increasing, agricultural production will need to incur large methodological and geographic shifts in adapting to climatic variability (FAO, 2011b and Lankoski *et al.,* 2018).

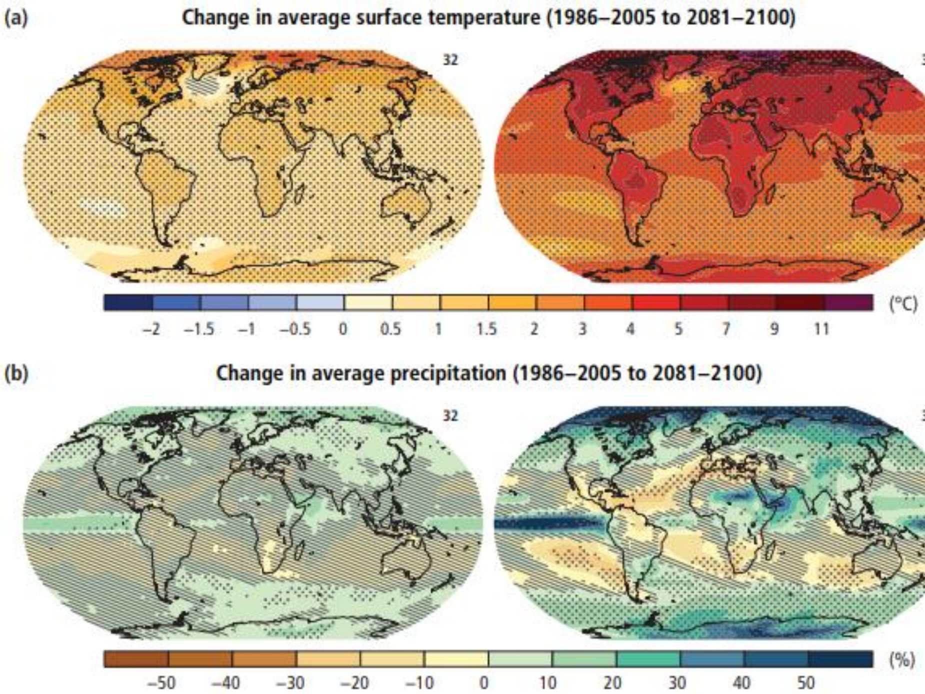

Figure 2.9 – Change in average surface temperature (a) and change in average precipitation (b) between 1986-2005 and 2081-2100. The numbers 32 and 39 at the top of each panel represent the number of models used to calculate the multi-model mean. Source: (IPCC, 2014)

In 2015, all members of the UN adopted the 17 sustainable development goals (SDGs) as part of the 2030 agenda (United Nations, 2020). The WWF (2019) identified five target areas for transformative change for a low-carbon and equitable food system in South Africa (Figure 2.10). Each of these chosen areas fall within the reach of SDG's related to the food system, namely: clean water and sanitation, life on land, responsible consumption and production and zero hunger. The adoption of transformation strategies in South Africa that are aligned with global initiatives such as the SDGs, gives hope for the survival of future agricultural production systems.

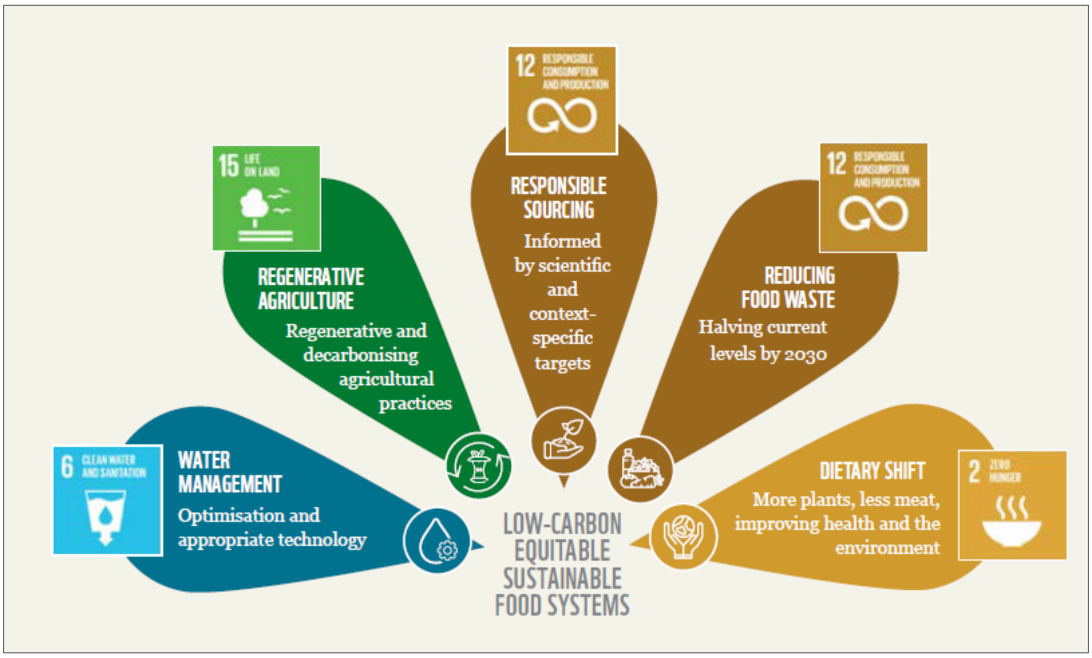

Figure 2.10 - Low-carbon equitable sustainable food systems. Source:(WWF, 2019)

With further research, regenerative farming systems could offer increased food production and ecosystem services (Pearson, 2007). The transition to climate resilient food production will take time and require farmers to overcome the barriers in adopting alternative agricultural practices. According to Wreford *et al.,* (2017), potential barriers at a farm level could be structural, financial or social. Structural barriers exist for farmers that do not have extended security on their land as they lack incentive to implement long-term greenhouse gas (GHG) mitigation schemes or to invest in complementary enterprises. The financial barriers are mostly net profit related where small to medium scale farmers are unable to afford the short-term loss in crop production or initial adoption costs associated without access to significant credit facilities. Finally, social barriers exist in some farming communities where traditional or emotional factors reduce a farmer's risk appetite and acceptable level of uncertainty.

2.3.3.2. Food sovereignty

The increasing need for agro-ecologically based food production systems to feed the growing population has been established in Sections 2.3.2. and 2.3.3.1. In addition to increasing food production in a climate resilient way, agro-ecologically based farming systems also have an important role to play in food sovereignty, which has been defined as the following (Altieri *et al.,* 2012):

"…the right of everyone to have access to safe, nutritious, and culturally appropriate food in sufficient quantity and quality to sustain a healthy life with full human dignity."

The IPCC (2014) predicts that between 2010 and 2029, the decrease in food production yield as a result of climate change could surpass the increase in yield of food production (Figure 2.11), resulting in negative overall growth rates. This trend is predicted to gain in severity as the decrease in yield is forecasted to be at least double the increase in yield from 2030 onwards. For South African crop and livestock producers this is a difficult trend to internalise as it paints a dismal picture for profitable food production in future.

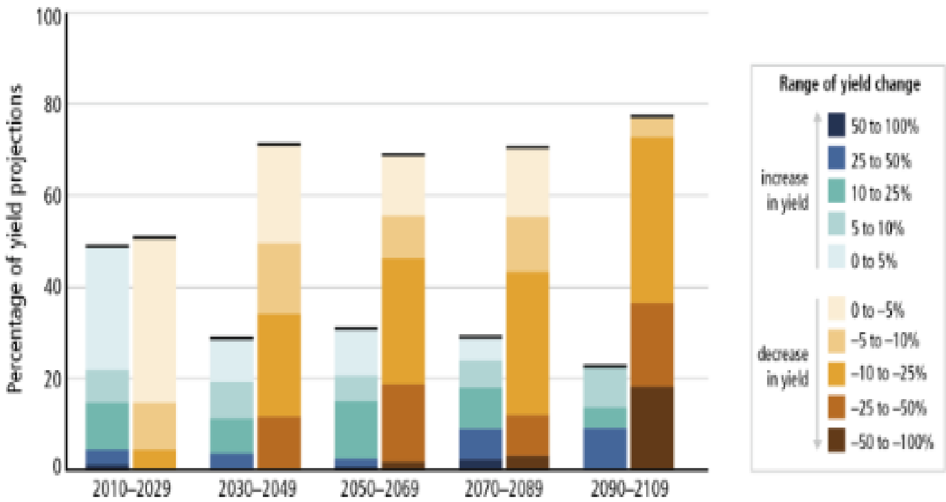

Figure 2.11 - Food production yield projections 2010-2109. Source: (IPCC, 2014)

High levels of income inequality have left the South African economy divided in terms of accessibility to food. Only 45.6% of South Africa's population are classified as food secure while the remainder struggle to access their right to food (WWF, 2019). For South African consumers that have a choice in the food they eat, value for money and convenience foods are at the helm of changing food demand. However, affordability and access are not the sole determinants of consumer food choices. The environment created by the private sector for consumers in shops, neighbourhoods and social media are a prominent determinant for consumer decision-making in the food system. With increased levels of education, consumers tend to be more aware of eating safe and nutritious food. The price of healthier food can be a deterrent for consumers to move from nutrient deficient fast and convenience foods.

2.4. Assessing agricultural systems

In an agricultural context, a system may consist of two or more components that work collectively towards producing and converting natural resources toward a clear purpose (Peart *et al.,* 2004; Jones *et al.,* 2017). The processes and operational activities conducted when producing and converting natural resources into usable forms are usually aligned with clear management goals and strategies to reach overall farm profitability (Peart *et al.*, 2004).

The ability of a farmer to deconstruct a complex agricultural system relies on the relative success of attaining an optimal allocation of scarce resources that can enable the selection of the best possible outcome that yield the highest level of efficiency and at the lowest cost. The use of financial tools to report on the implications of agricultural systems is an important step for farmers to take. Financial tools facilitate the comparison of all possible outcomes and to subsequently select a strategy that holds the most potential to enable agricultural systems' optimal potential (Mayer et al., 1998). Agricultural systems need to be reviewed constantly and realigned to the ever-changing financial and biological decision-making environments. Peart *et al.* (2004) identify changes in areas such as: weather patterns, technology, consumer behaviour, farm vision and the political environment as areas where farmers require symmetrical and up to date information to successfully manage agricultural systems.

In addition, agricultural systems also require verification through financial assessment and measuring processes. Verification activities provide key stakeholders in agricultural systems with the assurance that the current system implemented can continually be aligned with the strategic goals of the farm and can perform at an acceptable level in the shorter term (Peart *et al.*, 2004). To this end, Peart *et al.* (2004) propose a six-step feedback loop of verification, illustrated in Figure 2.12, to continually improve performance and correct imperfections. Key stakeholders in agricultural systems such as farmers, banks and intermediaries, must continually revisit actions taken or changes made which are no longer applicable or beneficial. Revisiting these actions or changes can be a cumbersome process and can lead to redundancy where information was previously correctly processed and analysed. However, verification activities still remain an important factor in the accuracy of decision making.

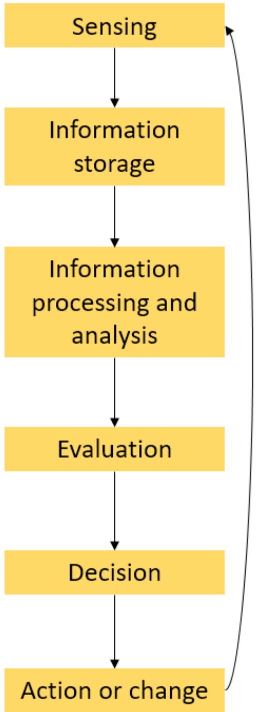

Figure 2.12 - Six-step feedback loop of verification. Source: Adapted from Peart et al. (2004).

2.4.1. Modelling agricultural systems

When farmers or researchers study the relationship between production practises and continuity within agricultural systems, there are four modelling approaches that can be implemented. A modelling approach can be derived from the field of econometrics, accountancy, simulation, optimisation or a combination thereof (Weersink *et al.,* 2002). When deriving/developing a model to represent an agricultural system, each of these approaches can be used to add additional dimensions of complexity and accuracy. For the purposes of this study, a closer look will be taken at the applications of simulation and optimization modelling through the lens of basic accounting principles.

2.4.1.1. Simulation modelling

Simulation and optimisation models (SOM) are built on the foundation of equations and inequalities, aimed at mimicking agricultural systems. SOM are used to approximate and represent real farming systems. By simulating and optimising real farming systems, farmers are able to create potential scenarios and to construct solutions to problems in advance without the detrimental cost of real-life trial and error (Weersink *et al.,* 2002). Structurally, SOM's can be built around static information from a fixed point in time or dynamic information where information may change over a given period. The time structure chosen for a SOM can impact the effect of risk elements, the range of parameters considered or accuracy of the model (Weersink *et al.,* 2002).

The complexity of the farming environment requires farmers to continuously make decisions that could have a limited or lasting impact on future farm profitability. The risk involved in decision making increases with the number of enterprises, management strategies and factors affecting profitability. To ensure that risk is minimised and complexity is accounted for, it is important that farmers also apply a holistic approach to the structure of their farming system. Simulation modelling is a versatile tool that can be used by farmers to apply a holistic approach in managing their farming systems and to gain a better understanding of the relationships between the key production factors, complementary enterprises and strategic goals (Mayer *et al.,*1998).

Mayer *et al.* (1998) identifies three challenges in modelling farm-level agricultural systems that are important to the context of this study. The first challenge is to reduce the vast number of variables in production systems. Only the core variables that are key in supporting the strategic vision of the farm in question should be simulated. For example, if a farmer in the Southern Cape is moving towards a zero-till approach to crop production, less emphasis will be placed on crop yield in the short term and greater emphasis will be placed on the financial effect of readjusting the assets and input structures of the farm to the new production strategy. This example is also relevant to the second challenge of modelling farming systems which involves reducing the number of management decisions. For a mixed crop-livestock farmer in the Southern Cape, adjusting the focus of a farming system from conventional soil tillage to zero-tillage with cover crops could integrate management decisions into a cyclical form where cover crops can also be grazed by livestock. The final challenge in modelling farm-level agricultural systems as identified by Mayer *et al.* (1998) is the potentially restraining factors of time and level of adaptability. Time can either be a forgiving or limiting factor in the modelling of agricultural systems.

The continuity of the financial and environmental benefits of moving to a zero-till approach in crop production can take time and may require changes to be made to the composition of the existing system. The dynamic nature of time and need-based alterations of farming make it difficult to accurately simulate an entirely accurate financial outcome. Modelling a farming system through simulation is thus not an exact science but does allow farmers to prepare their operational management strategy according to their appetite within the risk neutral environment.

When conducting a study on simulation modelling, it is important to incorporate a component of practical data and indigenous knowledge of the farming system to ensure that the model developed, is useable and not just theoretically possible (Whitbread *et al.,* 2010). The simulation model developed for this study is based on inputs from farmers and experts on agro-ecological aspects of farming systems in the Southern Cape.

2.4.1.2. Limitations of modelling agricultural systems

Due to the continual pressure exerted on agricultural systems by factors beyond the immediate control of the decision maker and the continuous development of new problems in the real world, simulation models are limited to approximations of future values and are often based on historical values (Nuthall, 2011). Three key limitations of modelling agricultural systems are discussed below.

Firstly, estimates are used to represent certain aspects of agricultural systems. Approximations make it possible to solve the problem at hand when the researcher needs relatively accurate information to conduct profitability forecasts regarding potentially feasible farming system alternatives. When modelling a farming system, a combination of estimated and real information can be used which if not done correctly, could increase the risk of varying accuracy levels in the representation of a physical farming system. The most efficient way to combat this inaccuracy is to overlook or revisit certain decision variables and factors that are beyond the farmer's control by assuming identical conditions when modelling the agricultural system (Nuthall, 2011). For example, researchers calculating an average crop yield may need to ignore the crop losses from an isolated crop disease in a particular year to avoid offsetting an average yield over all the years assessed.

A second limitation of modelling agricultural systems lies within the example above. If the crop disease persists over multiple years, the average crop yield calculation should be revisited and changes made to the model. By initially estimating variables in farming systems, the continued updating of information, can delay the final outcome to a later date (Nuthall, 2011). To derive the ideal whole-farm state, simulation models are used to generate and compare many different alternatives, variables and management decisions. Given the time and capital constraints inherent to farming systems, the generation of possible scenarios can complicate and distort decision making if a scenario materialises in a real farming system that was not predicted to.

Finally, farm models are designed and built for a specific farming system and cannot be applied to a new farming system until the necessary alterations have been made (Nuthall, 2011). This flaw reduces the ability of simulation models to be generically applied to solve problems across geographic farming areas in a fluid manner.

2.4.2. Crop-livestock systems in Southern Africa

In Southern Africa, many farming systems integrate complementary enterprises either for the sake of simplification or diversification. The combination of crop and livestock systems into a single coherent system, can reduce farm-level input costs and contribute toward greater net profit levels (Williams *et al.*, 1999). By combining crop and livestock systems on intensive farms, farmers can use the mutually beneficial outputs of each system's biological and financial processes to mitigate the costly and environmentally damaging effects of sustained commercial farming practices. By cultivating and grazing grasslands in rotation with cash crops, farmers are able to improve carbon sequestration, nutrient flows and soil structures (Lemaire *et al.,* 2014). The addition of a crop or livestock system to an existing farming system, not only provides additional profitability through the utilisation of mutually beneficial processes between systems, but also provides farmers with a risk coping mechanism (Williams *et al.*, 1999). For example, if a cash crop loses its market value due to the growth of harmful bacteria deemed not safe for human consumption, the farmer can still allocate a feed value to the crop grown if it is to be fed to livestock.

Agriculture in Southern Africa is challenged by various ecological and socio-economic issues such as dry climates, degraded soil, poverty and limited resources to afford additional labour. When taking a whole-farm approach to the formation of a coherent farming system, it is important to note that there is an opportunity cost involved in adding a component or enterprise due to the dependence on the availability of various finite production resources.

2.4.2.1. Modelling crop-livestock systems

When a complex farming system consists of various enterprises, an interdependent cycle is formed where each enterprise has a role to play in the successful operation of the whole-farm system. A model built to represent crop-livestock systems should reflect this cycle as accurately as possible representing each system both individually and as a component of the whole farm system. Failure to do so could end up in a diversion between short-term operational goals and the farm's long-term strategic goals.

Constructing custom-built simulation models for every farming system would be ideal but, in most cases, this can be too time consuming and costly. Existing crop-livestock models inherently vary in purpose, level of detail and types of production systems but can be adapted to suit specific conditions (Thorne, 1998).

2.5. The farm decision-making environment

Decision making is arguably the most important element of a farming systems approach. For an agricultural system or analysis tool to be used, a series of decisions must be made sequentially. The level of complexity in a farm decision-making environment depends on the ability of the decision maker to address the factors that adversely affect the decision to be made.

The decision-making environment can be divided into internal and external aspects. Farmers have control over internal aspects of the decision-making environment but not over external aspects. An example of an internal aspect would be a farmer's personal decision on when to sell sheep to the abattoir. An example of an external aspect might be a national law on land reformation forcing farmers in demarcated regions to surrender their land to communities that cannot access land. It is pertinent that each farmer's problem solving assessment accounts for both the internal and external factors by modelling estimates of various possible outcomes (Nuthall, 2011).

Due to the unpredictable and complex nature of the farm decision-making environment, strategies to offset the elements of risk and uncertainty are vital to sustainable farm profitability. Broadly put, risk is the probability of the event occurring, while uncertainty cannot be measured (Knight, 1921 and Hardaker *et al.*, 2015). An everyday application of the measurable risk is the integration of probability into the structure of insurance policies. Farmers in the Southern Cape who choose not to hedge the risk of adverse weather destroying an uninsured bumper cash crop are allowing the element of risk, facilitating complexity in the decision-making environment. In contrast, a sheep farmer in the Southern Cape would face uncertainty if a sudden ban was enforced on wool exports after a sudden outbreak of foot and mouth disease (FMD) in a neighbouring region.

In deciding which strategy to follow when formulating a final decision, farmers strongly rely on intuition and past experiences. Once a strategy is chosen, the subsequent process of implementing the strategy is equally important. The importance of intuition and past experience is illuminated in situations where new farm managers lack the required indigenous knowledge of the whole-farm system to accurately compile and implement a strategy to solve a particular problem (Nuthall *et al.*, 2018). A decision maker with strong intuition and a vast collection of past experiences of managing whole-farm systems would be in a better position to compile a risk-reducing strategy within the parameters of their farm decision-making environment.

When faced with the challenge of solving a cumbersome problem, decision makers need access to cohesive and coherent information feedback loops. In Figure 2.13, the cohesive nature of information and the importance of coherent feedback loops are illustrated by the inability of actions to take place without the connection of information flows from activities, desires and decisions.

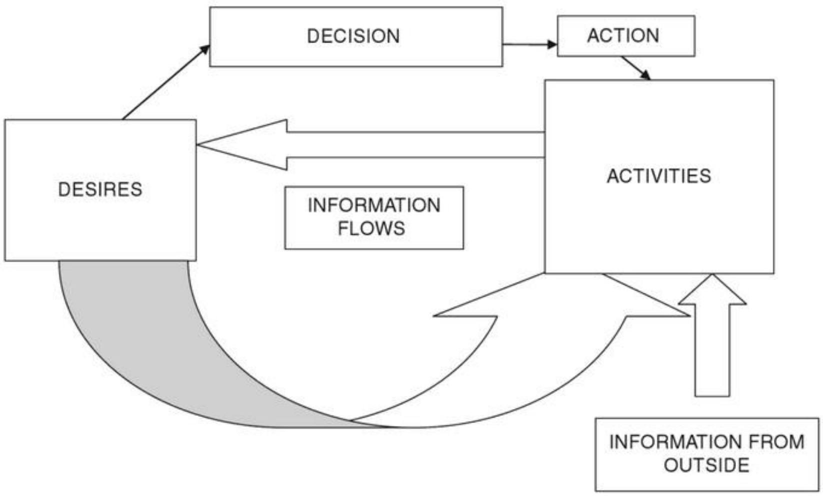

Figure 2.13 - Problem solving flow chart. Source: (Nuthall, 2011).

When facing a problem under relaxed or stringent time constraints, farmers are tasked with analysing as many available courses of action as possible before selecting an optimal solution. To improve the analysis of available courses of action, farmers can use various analytical tools within the broad body of literature on simulation modelling.

2.6. Multidisciplinary group discussions

In this study, a whole-farm budget model was derived to assess the financial implications of soil regeneration in the Southern Cape. The ability of this budget model to assist the farming community and future research in the Southern Cape regarding regenerative agriculture, hinges on the accuracy of the estimates and forecasts developed during the derivation of possible production scenarios.

The use of a holistic approach in assessing agricultural systems has developed over time with key contributions made by the research disciplines relevant to each system component. The outcome of an agricultural system is the end result of an interaction between its components. When taking a holistic approach to simulating an agricultural system it is necessary to include as many experts or producers as possible to share knowledge from each system component.

The benefit of having diverse inputs when constructing a budget model is not only to understand the role played by each system component but also the nature of interaction between each component (Jones *et al.*, 2017). For example, when making biological assumptions regarding the number of sheep that can be grazed on cover crops in a regenerative farming system, expertise is needed to aid in the determination of a plausible increase in carrying capacity. The natural interactions between each of these components illustrates the need for multidisciplinary inputs to understand the relationship between all the components in a cover crop system. To ensure the most relevant and accurate information for this study and to ascertain the correct budget model parameters and assumptions, the expertise from individuals who are well acquainted with farming systems in the Southern Cape is needed. To guarantee the usability and relevance of this study to the crop and livestock industry, the discussion group participants should be carefully selected to warrant a clear connection and balance between theory and practise. Examples of professionals, aside from trial staff and local farmers, required to provide this connection may include (Hoffmann *et al.,* 2011):

- Agricultural economists
- Agronomists
- Soil scientists
- Plant pathologists
- Entomologists
- Animal scientists

On a practical level, multi-disciplinary group discussions allow for the collection of information in a structured environment where information can be shared across research disciplines and cross examined for validation. According to Hoffmann *et al.,* (2011), there are two limiting aspects of multi-disciplinary group discussions. Firstly, the inputs of a group member may be impacted by the opinions of other group members perceived to be well established in their field. Secondly, the cross examination of information may derail the envisioned creative and progressive research environment and reduce it in the validation of information.

2.7. The financial aspect of agricultural systems

2.7.1. Budgeting

Agricultural systems rely heavily on operational and strategic plans that are both effective and efficient in the allocation of finite on-farm resources. Budgeting is an analytical technique and tool that can be used to detail such plans to make improvements to agricultural systems. Budgeting techniques are able to accomplish this by describing the physical aspect of agricultural systems and reporting on the financial aspect (Nuthall, 2011). A successful budget will require in-depth farmer knowledge of the physical farm system and a set of pre-determined assumptions to make estimations regarding the financial aspect of agricultural systems.

Upon successful completion, budgets can provide farmers with a cost-effective means of estimating future profitability, cash flow and physical factors (Nuthall, 2011). Budgets can, however, be inefficient if researchers aim to compare numerous systems and to simultaneously actively account for elements of risk. Risk analysis and system comparisons can be incorporated into budgets in the form of risk reducing approaches and comparative budgets. Comparative budgets are either used to assess a component of a farm in the form of a partial budget or to compare the whole-farm system over time with a developmental budget. Partial budgets not only assess the fixed and variable cost aspects of a farm system but can also be used to assess the implications of a single technical unit if the researcher only wishes to consider certain costs.

Whole-farm budgets allow farmers to compare the different sub-systems operating on their farms and to ascertain a profit maximising point during the consumption of scarce resources. Profit maximising outcomes can be derived using information collected at a certain point in time on fluctuating factors in a farming system such as production output units, market prices for produce or the cost of inputs used (Lien, 2003).

A farmer’s ability to create a perfect whole-farm budget is constrained by continuously changing information and the inability of tools such as a sensitivity analysis to simultaneously consider two or more possible results (Lien, 2003). Decision making based solely on budgeting can reduce the accuracy and efficiency of the farm decision-making environment. The reason for this is partly because the results generated by whole-farm budgets can distort strategic planning and long term profitability as a result of the wide margin for error that can be incurred when making physical estimations and compiling various individual enterprise budgets (Nuthall, 2011).

The extent and nature of the solution needed to solve farm problems may require an alternative approach to standard budgeting. Alternative methods of budgeting will be discussed in the following subsections.

2.7.1.1. Parametric budgeting

Parametric budgeting allows researchers to determine the effect of price changes in non-predictable factors of profitability. Non-predictable factors may include meat prices, crop yields or fuel prices. Functionally, parametric budgets consist of an equation where non-predictable factors, represented by symbols and constants derived from a normal budget are used to forecast profit levels (Nuthall, 2011). Parametric budgets aim to prove the same result as a standard budget but can illustrate the results in a different manner. If represented graphically, the results of parametric budgets can show the relationship and future trends between two non-predictable factors. This equation proves useful in situations where profit estimates are needed to assess the implications of different combinations of non-predictable factors (Nuthall, 2011).

A final important use of parametric budgeting is the possibility of determining the conditions under which one system might be preferred to another. For farmers looking to adopt regenerative practises in the Southern Cape, parametric budgeting may assist in assessing the preferred level of profitability between conventional, conservation and regenerative systems. By substituting non-predictable factors and constants into the equation, farmers can test possible combinations of inputs and costs that will lead to the highest level of profitability.

2.7.1.2. Gross margin analysis (GMA)

GMA can be used to indicate to the farmer which farm products are most profitable to produce. A gross margin is the difference between the gross revenue generated by output and the variable cost per unit produced (Nuthall, 2011). GMA can be applied to farming systems to either ascertain the level of efficiency that a particular enterprise imparts to the whole-farm system or to assess the suitability of enterprise combinations (Peart *et al.,* 1962).

A farming system's cost structure can be divided according to expenses related to the specific enterprises and the costs that are imbedded in the whole-farm system (Peart *et al.,* 1962). Distinguishing between variable costs and fixed costs is an important step towards a whole-farm approach as it acknowledges that farming systems consist of inter-related enterprises that can be holistically combined during whole-farm planning (Peart *et al.,* 1962). Empirically, fixed costs will remain constant year-on-year, irrespective of any farming systems that are implemented or removed (Nuthall, 2011). An example of a fixed cost would be water rights or property rent payable each year by farmers in the Southern Cape. Variable costs; however, share a close correlation with enterprise output levels. As enterprise outputs increase (decrease), the variable cost incurred will also increase (decrease) (Nuthall, 2011). For example, on a cropping farm in the Southern Cape, tractors that are driven more often during peak times of the year result in a fluctuating fuel cost.

2.7.2. The probabilistic approach to budgeting

The standard approach to farming systems analysis, assumes static information from a fixed point in time which limits the amount of information available to the farmer making the decision (Milham *et al.,* 1993). The probabilistic approach provides the decision maker with more information on the problem at hand by constructing projections of future outcomes under the given conditions. A probabilistic approach to budgeting will be followed in this study. The main issue with this approach is the possibility of biased or channelled interpretation of the results. The researcher or farmer estimating a production outcome or production decision could skew reality to favour outcomes that are thought to be ideal or to avoid high risk outcomes (Milham *et al.,* 1993). If the assessment is 'tampered' with, potentially beneficial outcomes could be omitted and not considered which could undermine the value of the research conducted.

2.7.3. The stochastic approach to budgeting

To account for the elements of risk and uncertainty in the farm decision-making environment discussed above, it is necessary to move towards a simulation model that can account for possible changes in farming systems over a given period (Lien, 2003). A stochastic budgeting model can be used to simultaneously simulate various existing farming operations, account for random elements of uncertainty and to forecast the potential financial performance of a whole-farm system (Milham *et al.,* 1993). A stochastic approach to budgeting will not be applied in this study. With access to simulated information on elements of uncertainty and future financial performance, farmers in the Southern Cape could make well informed decisions on how to solve problems, implement regenerative practices or maintain current operations using stochastic budgeting (Milham *et al.,* 1993).

In practise, stochastic budgeting allows farmers to see how risk and profitability could be affected should one of the alternative financial action plans be implemented. RISKFARM is an example of a simulation model used in farm system analysis that applies management accounting principles to account for uncertainty surrounding the financial and functional aspects of farming systems (Milham *et al.,* 1993). In essence, the aim of RISKFARM is to measure the performance of the financial and risk aspects if changes were to be introduced to the farming system (Lien, 2003).

2.8. Conclusion

The combination of theory and practice form a formidable bond in the creation of meaningful research. Similarly, the application of farming systems theory to the current farming environment in the Southern Cape as well as an ongoing trial offers continuity and usability of the knowledge developed in this study.

The purpose of this chapter was to unpack the theoretical concepts on the holistic approach of regenerative and systems thinking in an agricultural context and to apply it to the notion of introducing purely regenerative farming practises to farming systems in the Southern Cape. This was achieved by organising existing literature into a logical sequence to review the key aspects of regenerative agriculture and systems thinking. Part one and two of this chapter contextualised the progressive nature and value of regenerative farming and thinking in modern agriculture. Parts three and four briefly addressed the importance of a whole-farm systems approach to agriculture, the farm decision-making environment and in modelling farming systems. The final two parts of this chapter entailed a discussion on the conceptual applicability of budgets and multidisciplinary discussion groups in assessing the financial implications of regenerative agriculture to Southern Cape farming systems.

By using a logical sequence in reviewing these concepts, key insights were gained into the broader context of this study. The next chapter is a discussion on the context and structure of how the results and findings of this study will be assessed.

Chapter 3: Applying farming systems thinking to a typical farm in the Western Rûens

3. Introduction

In Chapter 2, the theoretical concepts on regenerative farming and systems thinking are unpacked and applied to certain examples relevant to farming systems in the Southern Cape. In this chapter, the concepts discussed in Chapter 2 are applied to the farm level and explained according to the thought processes that underpin the financial assessment of regenerative agriculture in the Southern Cape.

This chapter consists of five sections. In the first section, the geographical context of this study and the relevance of a soil regeneration trial in the Southern Cape are established. In the second section, the use of typical farm theory as an explorative tool to simulate potential production scenarios on a typical farm in the Western Rûens is discussed. A brief description of the characteristics of a typical farm in this area is also included. The third and fourth sections outline the basic structure of a budget model and the functional role of a multidisciplinary discussion group in validating the assumptions and parameters of a budget model. The chapter concludes with a discussion on how scenario planning can be used to assess various production scenarios of future crop and animal production in the Southern Cape under regenerative farming practices.

3.1 The Rûens homogenous farming area

No two farming systems are identical but there may be similarities in production conditions within a relatively homogenous farming area. Conditions such as average, minimum and maximum temperature, soil type and average rainfall can be relatively homogenous within a geographic area. This allows for assumptions to be made on various farming input and output requirements. The Rûens is such a relatively homogenous farming area within the Overberg that includes the Caledon, Swellendam, Heidelberg and Bredasdorp districts (Louw, 1989). The Rûens can be sub-divided into smaller homogenous areas called the Western, Southern and Eastern Rûens (ARC Small Grain Institute, 2020; Annexure A).

The trial applicable to this study is based in the Western Rûens and the agricultural environment of this area will serve as a basis for the selection of basic farm parameters and assumptions necessary for simulating a farming system. The environmental conditions in the Western Rûens resemble a mediterranean climate with annual rainfall quantities peaking during the winter months between April and September (Matebesi *et al.*, 2009; Figure). Average temperatures vary during the year with lows of 6.0 °C during the winter months and highs of 28.8 °C in summer months (Matebesi *et al.*, 2009).

By combining secondary data collected by reputable businesses in the local agricultural industry in the Western Rûens and the input from experts and producers, a farming system that is representative of the homogenous farming area is identified. While the use of a representative or typical farming system will limit the ability of the simulation model to assess the financial implications of a specific farm, the scenarios tested in Chapter 4 could potentially assist farmers in assessing the major challenges that they may face when incorporating regenerative practices into their conservational farming systems.

3.1.1 Tygerhoek Research Farm

Tygerhoek research farm (34.1481S 19.9028E; Figure 3.1) is situated in the Western-Rûens near Riviersonderend in the Southern Cape. Tygerhoek belongs to the Western Cape Government and is divided into numerous sub-camps for various agricultural trials. The research conducted at Tygerhoek is largely based on dryland winter cereal cropping and livestock production, suitable to the Rûens homogenous farming area (Cloete *et al.,* 2016).

Winter rainfall is an important production factor in the area and in the ongoing trials. The long-term average rainfall is 470.1mm per annum, of which, approximately 205.6mm falls in the summer months and 264.5mm in the winter months between April and September (Cloete *et al.,* 2016; MacLaren *et al.,* 2019 and Strauss, 2020a). Figure illustrates the distribution of the average monthly rainfall at Tygerhoek Research Farm from 2010 to 2019.

Figure 3.1 – The geographic location of Tygerhoek Research Farm (34.1481S 19.9028E). Source: Google Maps (2020).

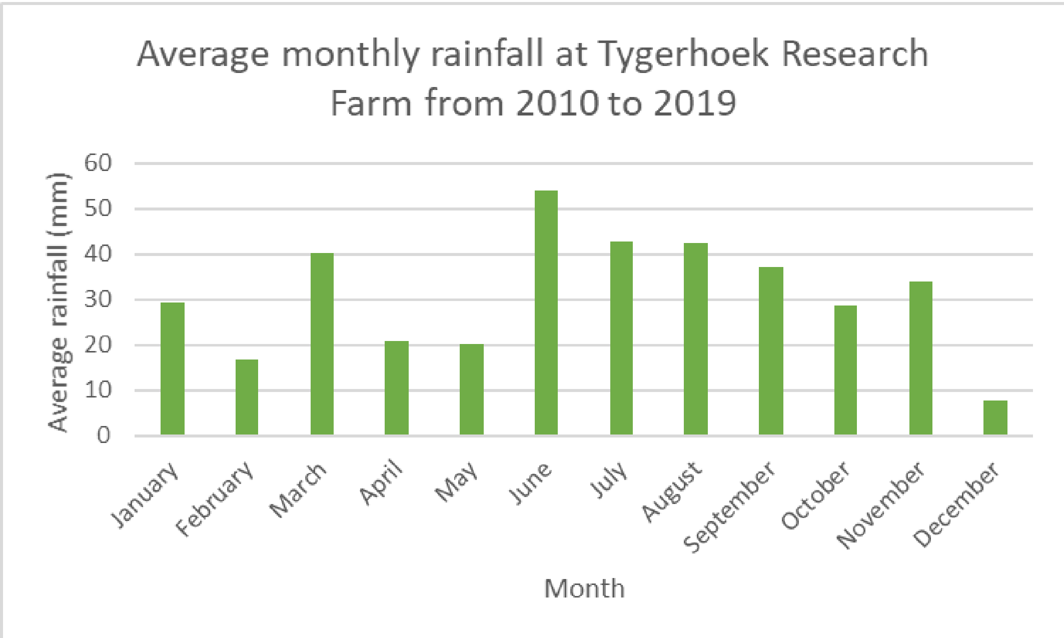

Figure 3.2 – Average monthly rainfall at Tygerhoek Research Farm between 2010 and 2019. Source: Smorenburg (2020).

3.1.1.1 Soil regeneration trial

In 2019, a trial to assess the possibilities surrounding soil regeneration and the subsequent impact thereof on crop and animal production in the Southern Cape was started by the

Western Cape government. This trial can subjectively be considered as pioneering in the assessment of regenerative farming practices in the Southern Cape. The trial will serve as a point of reference for this study and more specifically as a basis for the simulation of potential production scenarios presented in Chapter 4.

Regenerative farming practices vary amongst systems but all are based on the same founding principles illustrated in Figure 2.1. As discussed in Section 2.2.4, there is currently international research being done on regenerative farming systems under farm specific production conditions. Many of these research facilities abroad have favourable environmental conditions that increase the rate of activity in the soil and thus the effectiveness of the farming system. In the Southern Cape cold and wet winters tend to result in lower crop yields than areas with summer rainfall, higher temperatures and snow cover in winter (Strauss, 2020b). The initiation of the trial at Tygerhoek Research Farm has opened a door of opportunity for purely regenerative agricultural practices to potentially make meaningful headway into the Southern Cape.

A camp at Tygerhoek research farm was made available for smaller trials. Six of the ten sub-camps are used for purposes of this trial. Figure 14 is a graphical representation of the layout of the trial at Tygerhoek. Each replication consists of two sub-camps, represented by the green block and the yellow block in Figure 14. The green sub-camp will be planted with winter and summer cover crops, which will be grazed by sheep using high-density grazing management practices in repeats one, two and three. The sub-camp indicated in yellow, is divided into three strips: repeats four, five and six. Each repeat is planted with three strips of cash crops (wheat, barley and canola). Pollinator strips will be implemented alongside the outside borders of each sub-camp. The six repeat camps will be split horizontally into sites one and two for Biochar application. Site one will receive no Biochar and site two will receive Biochar. The Biochar will be applied annually to the same area. The trial will continue for 12 consecutive years to allow each camp to undergo all of the trial processes twice.

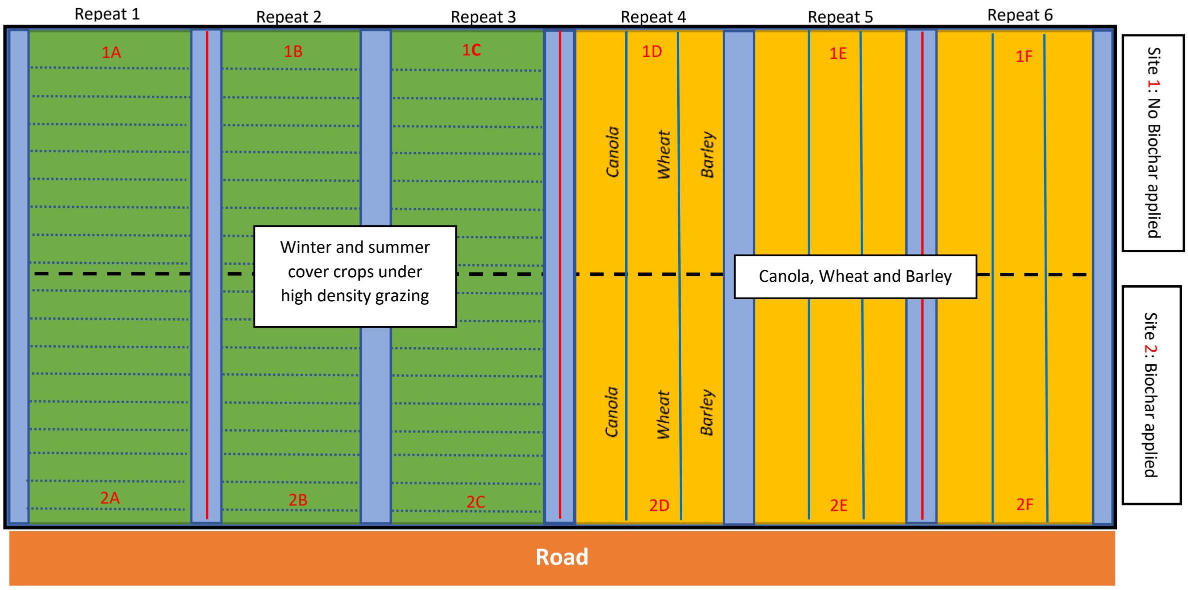

Figure 14 - A graphical representation of the Soil Regeneration Trial at Tygerhoek Trial Farm. Source: Adapted from Smorenburg (2020).

3.2 Typical farm theory

When conducting research on a farm level, it is important that the data collected is processed timeously and applied to the scope of the study at hand. Farm level data is typically collected in the form of an individual farm survey, regional reports or through simulation (Feuz *et al.*, 1990). There are empirical similarities between these methods of data collection. Each method requires careful consideration for the research question in the study at hand, ensuring the data collected is processed in a meaningful way. For this study, the data needed to assess the financial implications of regenerative agriculture in the Western-Rûens farming area was entered into a multi-period whole-farm budget model. The budget model was then considered and validated by a group of experts and farmers during a multidisciplinary discussion. The suggestions and inputs from the group discussion were used to formulate the parameters and assumptions necessary for the construction of a typical farming system in the Western Rûens.

As regenerative farming practices are not yet formally identified or described in the Southern Cape, the nature of this study remains explorative. The use of a farm survey or regional data can be expensive, time consuming and case specific. The explorative nature of this study is well suited to simulation modelling. Simulation modelling can be used to apply explorative and hypothetical changes to an existing conservational farming system in the Southern Cape, heading towards the incorporation of purely regenerative practices. Additionally, this study uses data that can be considered as representative of the surrounding farming area and could potentially be adapted, on a site-specific basis, to be applied to a particular farm.

A possible disadvantage of simulating data for an existing farming area, such as the Western Rûens, is the inaccuracies that may occur in making assumptions regarding production norms or market prices. A lack of conciseness in the simulation of farm level data can result in a divergence between the practical and theoretical aspects simulated in the budget model (Feuz *et al.*, 1990). The aim of the simulated farm is to establish a basis for comparison or alternative production orientations.

Alternatively, the concept of the typical farm can be viewed through the lens of representative firm theory used by economists such as Alfred Marshall (Feuz *et al.*, 1990). Through this perspective, the typical farm is an approximation of the average farm in the Western-Rûens homogenous farming area. An approximated or representative farm will be free of outlier effects that can impact the results of mean calculations. Under this assumption, the typical farm would represent the element of normalcy endemic to a homogenous farming area where market conditions, production activities and management approaches are conducive to financially viable outputs. A typical farm may inherently fail to account for every cost or production parameter that occurs within a homogeneous farming area but can provide insight on how profitable the use of machinery, enterprise combinations and management approaches are under purely regenerative farming principles.

The use of a typical farm to represent a geographical area of farms not only facilitates research cost benefits but also the opportunity for researchers to make inductive conclusions about the trends and principles of a relatively homogenous farming area (Hatch *et al.*, 1982). The data and conclusions drawn from contemporary electronic simulations of the typical farm can be efficiently distributed to stakeholders in an agricultural value chain. This could improve forward and backward linkages within local farming industries.

On a farm level, access to area specific data can support complex decisions regarding enterprise gross margins, capital requirements and asset financing structures over the long term. Combining the opinions of experts from different disciplines and the experience of producers, the typical farming system modelled will be less susceptible to management bias and will assist in forecasting potential outcomes (Feuz *et al.,* 1990).

3.2.1 A typical farm in the Western Rûens homogenous farming area

A typical farm in this area has fertile Glenrosa soil that is suitable to grow various crops such as wheat, barley, canola, lupines and oats (Tainton *et al.*, 1987). From a farm management perspective, farmers in the Western Rûens utilise some Conservation Agriculture (CA) management practices which entail three basic principles.

The first principle of CA is minimum soil disturbance. Minimum soil disturbance implies that farmers should refrain from tilling the soil and directly planting seed into the soil, provided the disturbed area is less than 15cm (or less than 25% of the cropping area). The second principle of CA (perdurable soil cover) indicates that directly after seeding, ground cover of at least 30% should be maintained for the practice to be aligned with CA requirements (FAO, 2019). The third principle of CA pertains to the diversification of plant life by having at least three different crops per crop rotation. The application of CA principles should be adjusted to suit the needs of each farm individually (Knowler *el al.*, 2007 and Tambo *et al.*, 2018).

Regenerative farming practices have not yet been formally incorporated in Southern Cape farming systems. In this study, potential changes required to transition the typical CA-based farming system to a more regenerative farming system will be assessed on a whole-farm level.

3.3 The functional role of the multidisciplinary discussion panel

In Section 2.2.3, it was suggested that an agro-ecologically based farming system such as regenerative agriculture can be less capital intensive but more knowledge intensive. When assessing the financial implications of regenerative agriculture, it is important to ensure the accuracy of estimates made on production assumptions, parameters, and market information. Assessing the financial implications of a farming system also requires a combination of the scientific and practical understanding of interactions between the elements of time, space and management style on a farm. Each of these elements can be simulated in a whole-farm multi-period budget model and used as a basis to calculate selected financial indicators, used to assess whole farm profitability. To capture the impact of time, space and management style in a simulation model, agricultural experts and local producers with an indigenous knowledge of a relatively homogenous farming area are consulted to validate the financial and biological parameters of a farming system.

A discussion group can also be effective in unifying different ideas within a similar thought process. Instant responses can be given to questions posed by researchers. This reduces the amount of lead time typically incurred by researchers while waiting for feedback or to redistribute responses.

3.3.1 Discussion group preparation

Preparation for the discussion group began with the compilation of a preliminary budget model that served as a point of departure. A virtual discussion was conducted on the online platform, called Microsoft Teams. Participants were invited in advance to allow enough time to respond and reflect on the possibilities surrounding regenerative farming in the Western Rûens. Participants who agreed to partake, were sent a meeting agenda via electronic communication and were provided with details surrounding the potential production scenarios to be discussed and verified during the meeting. The aim was to combine theoretical concepts and practical ideas in a creative environment. Creativity was key to the development of potential production scenarios in this study, as regenerative farming is not yet significantly practiced in the Southern Cape.

3.3.2 Validating the structure of a typical farm in the Western Rûens

A multidisciplinary discussion group was held virtually on the 30th of September 2020 from 9am to 2pm. The objectives were:

- To validate a preliminary budget model that was constructed by the researcher.
- To discuss potential production scenarios that producers in the Western Rûens may face when transitioning from CA-like farming practices to purely regenerative practices.
- To validate the simulated information, expertise was required from the fields of agricultural economics, crop production science, cropping systems and animal production. Before the group discussion, each participant received an electronic copy of the agenda and a brief description of the preliminary production scenarios to be discussed. The key inputs made by each participant were noted and incorporated into the construction of the final budget model for this study. Verbal inputs given on a factual basis during the meeting were confirmed via written electronic communication within a week after the discussion group took place.

The following participants were present during the discussion and made valuable contributions:

- Mr. Pieter Blom, Agricultural Advisor, SSK Riversdale
- Mr. CD du Toit, Farmer in the Rûens area, Southern Cape
- Mr. Michael Gregory, Agricultural Advisor at Overberg Agri
- Mr. Clinton Hayward, Discussion group organiser and project leader
- Dr. Willem Hoffmann, Agricultural Economist at Stellenbosch University

- Mr. Pierre Laubscher, Agriculturalist at Overberg Agri
- Mr. Casper Nell, Agricultural Advisor at Overberg Agri
- Mr. Rens Smit, Scientific Technician: Directorate Plant Sciences of the Western Cape Department of Agriculture
- Miss. Lisa Smorenberg, Scientific Technician: Institute for Plant Science, Tygerhoek Research Farm.
- Mr. Piet Lombard, Scientific Technician: Institute for Plant Science, Tygerhoek Research Farm.
- Dr. Johann Strauss, Plant Sciences and Sustainable Cropping Systems Research at the Western Cape Department of Agriculture.

3.4 The structure of a whole-farm budget model

To assess the financial implications of regenerative farming practices in the Western-Rûens as accurately as possible, the budget model used in this study was based on a typical farming system in this area. This allowed for the results of the budget model to be inferable to a wider geographical area and to assess the efficiency and feasibility of the simulated system.

A budget model is created to represent a whole-farm system over a longer period. This is achieved by using the Microsoft Excel spreadsheet program. It is a versatile electronic programme that can be used to instantly solve equations and represent data graphically in various interconnected sheets. Electronic spreadsheet programs are well suited to the simulation of whole-farm systems as each enterprise or component of the farming system can be assessed individually or in relation to the whole farm. The simulation of a farming system typically requires a point of departure, a processing phase and a stage of finalisation (Figure 15). Budget modelling in Microsoft Excel is thus an effective tool for assessing the financial position of a farming system as the biological and financial aspects are represented using standard accounting principles. The budget model thus integrates the physical/biological dimensions of the farm with the socio/economic dimension through a sequence of equations.

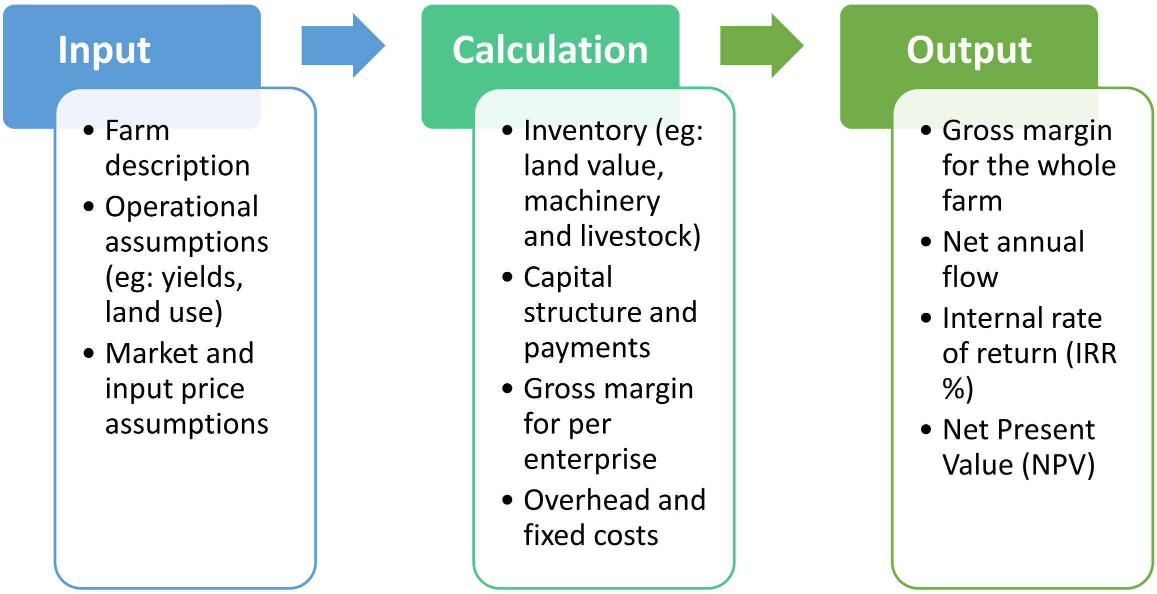

Figure 15 - The basic structure of a whole-farm budget model. Source: Adapted from Hoffmann (2010).

3.4.1 Inputs

This budget model is structured to be flexible, allowing for production and financial inputs to be changed and the results re-calculated instantly. The input component of a budget model serves as the foundation from which the calculation and output components can be compiled. The production input prices and market product prices selected, represent the farm parameters and can be changed instantly and the effect of the change on the whole-farm system can be interpreted in the calculation and output components.

3.4.1.1 Farm description

A mixed crop-livestock farming system functions on the premise that its components function synergistically toward a biological and financial outcome. To maintain a balance between the biological and financial factors, farmers must be aware of the farm parameters that can inhibit and expand production activities. Additionally, balance must also be maintained between the investment requirements and the operational functionality of farming.

When a farming system is simulated in the form of a budget model, the production activities need to adhere to the parameters imposed by limitations relating to farm size, soil quality, water availability and the proximity of the market. A multidisciplinary group discussion was used to improve the validity of the representation of physical aspects of a typical farm. This was achieved by incorporating the practical knowledge of farmers in Western Rûens and combining it with the biological and systems expertise of local industry stakeholders.

The physical dimension is a key component of the budget model construction and use, especially during the initial stages of simulating a farming system. An accurate farm description ensures cohesion and adequate alignment to the normal production parameters of a homogenous farming area. This contributes trustworthiness of the model uses to farmers.

3.4.1.2 Financial farm description

Once the physical parameters of the farm are specified, monetary values can be allocated to physical assets at a fair market value. This is done in the form of an inventory. Assets typically include land, machinery, livestock, equipment and fixed improvements (Hoffmann, 2010). The allocation of values to fixed and moveable assets is a necessary step for calculating, amongst others, machine depreciation, capital requirements and the value of marketable livestock. Each of these calculations is linked to the physical description of the typical farm. Certain changes made to the physical farm parameters can impact the values of the assets on the inventory list. For example, an adjustment in the carrying capacity of sheep on the farm will influence the numbers of sheep the farm can support in terms of feed.

Another key function of the inventory is to serve as a basis for the profitability calculation where profit is expressed as the yield (value) on the investment (value). The inventory reflects the investment requirement for the farm.

3.4.1.3 Farm input and output price data

The constant market price of farm inputs and outputs were used to construct the preliminary whole farm budget model. The prices were based on data collected by a reputable agribusiness that serves the Western Rûens farming area. The information compiled for the preliminary budget model was re-evaluated and validated by the discussion group in Section 3.3.2, for the inclusion of alternative management approaches and updated prices (Hoffmann, 2010 and Nell, 2020). The input and output prices used in a budget model directly affect whole-farm profitability by raising or lowering the cost of production or market value of outputs.

3.4.2 Calculations

The calculation aspect of a budget model plays an important role in ensuring the simulated farm inputs are correctly translated into measurable outputs whilst remaining in accordance with standard accounting principles. By using standard accounting principles, the results of the calculations can be verified and used as a means of comparison to other farming systems. Based on the assumptions and parameters of the input aspect, the machinery requirements, gross production value and gross margin of the typical farm can be calculated.

3.4.2.1 Inventory

The inventory of a farm is a valuable indicator of the assets and the capital required to run farm activities on a medium to long term basis. As discussed in Section 3.4.1.2, land, machinery (including implements), fixed improvements and livestock can be considered as assets in a farming business. Capital is required to pay for machinery, fixed improvements and the labour necessary to generate a revenue stream in a farming system. The inventory of a budget model is key in understanding the initial capital investment made to fund the hiring or purchases of assets needed to run the farming business.

Dryland farming systems in the Western Rûens heavily rely on machinery to conduct cropping and livestock activities. Machines are required for cropping and livestock activities such as planting, harvesting and transporting farm produce to the point of sale. Each farm has a unique set of machinery requirements based on the land area that needs to be worked, the time allocation and the capabilities of the machine or implement to be used (Hoffmann, 2010). During the group discussion farmers and industry experts discussed the machinery requirements for a typical farm, as well as the parameters of the machinery. Machines have a finite lifespan during which they need maintenance and eventually need to be replaced. Replacement can be an expensive exercise and needs to be carefully budgeted for. A machinery replacement schedule is used to keep track of the lifetime of all machines and to anticipate when a replaced machine will need to be financed. Depending on the farm strategy, medium term financing is typically used to finance machinery and the salvage value of a sold machine is also considered.

3.4.2.2 Enterprise gross production value and profit margin

An enterprise budget is constructed for each enterprise within a farming system. The purpose of this is to allow for the assessment of the financial feasibility of an enterprise on its own or as a component of the wider farm system. Enterprise budgets are constructed to be scalable and to illustrate the ability of an enterprise to generate enough revenue to account for the directly and non-directly allocable costs associated with production. The revenue of a crop enterprise can be derived by determining the product of expected yields, field size and the market value of the applicable output. Expected crop yields are either simulated according to producer experience or forecasted based on historical data. The yield quantity of a crop grown in a specific year with a poor or fair annual rainfall can be calculated as a percentage of the yield in a good year. In Section 4.1.1, the integral role of rainfall on crop yields is explained and applied into the crop rotation system simulated for this study.

3.4.2.3 Fixed costs

Fixed costs for a farming business do not usually vary during the year and can be anticipated and budgeted for. Fixed costs in crop-livestock farming systems can have a significant impact on whole-farm profitability and are not allocated to any particular enterprise costs. Fixed costs are however necessary overhead costs incurred to maintain the whole-farm operational sustainability. Fixed costs can include labour, bank charges, electricity, water rights, asset insurance or municipal taxes.

3.4.3 Outputs

The financial feasibility of a simulated farming system can be measured using the internal rate of return (IRR), net present value (NPV) and the annual cash flow (Hoffmann, 2010). These measures of profitability indicate the return on capital invested, the success of individual enterprises, the affordability of borrowed money and the whole farming system as an integrated unit.

3.4.3.1 Whole-farm profitability

Farming systems within a selected geographical area may have similar production factors but are rarely identical in the variables affecting farm profitability. When assessing the financial implications of a farming system, farm profitability is an important indicator to monitor as it shows the impact of changes in variables over time (Hoffmann, 2010). The use of scenario planning as a tool to simulate changes in variables will be discussed in Section 3.5.

The budget model simulated in this study is designed to model potential production scenarios over a period of 20 years. The length of time chosen to base a forecast on can vary between budget models simulated, depending on the nature of the study in question. The purpose of using a long-term budget to assess the financial feasibility of regenerative farming practices in the Western Rûens is threefold. Firstly, regenerative farming practices are inherently biologically focused. This implies that changes made to a farming system will likely have the long-term goal of replenishing nutrient cycles which requires time to reflect on whole-farm profitability. Secondly, the management of the capital required to finance the operations of a typical farm can only be effectively assessed after repeated annual cash flows have been generated to facilitate an assessment of the return on capital. Finally, the expected lifetime of machinery on a typical farm was estimated by the discussion group to be approximately 12 years. To assess the financial impact that changes in machinery might have on whole farm profitability, enough time should be allowed for all the machines to be replaced at the end of their expected lifetime.

The typical farm simulated exists within the biological and financial parameters of the Western Rûens homogenous farming area. To measure the changes required to transition a CA farming system to a purely regenerative farming system, the current financial position of a typical farm under CA should be established. The financial position of a typical farm can then be used as a “control” in assessing the financial implications of simulated changes to the system under regenerative principles. To assess the financial implications of these changes, both simulated farming systems will be considered in real terms without the effect of inflation.

The whole-farm gross margin is the sum of all the individual enterprise gross margins operating within a farming system. Enterprise budgets calculate the gross margin using a series of “If” formulas to consider expected production outputs during good, fair and poor rainfall years. In the constructed budget model, revenue is the product of a static market price and the predetermined output quantity produced by an enterprise. The predicted output of an enterprise, such as canola, was determined during the multidisciplinary discussion group and varies according to the expected yields anticipated during a good, fair and poor rainfall year. Annual fixed costs associated with the Western Rûens homogenous farming area were determined based on information provided by a reputable business in the local farming industry and were validated during the multidisciplinary discussion (Gregory, 2020). Additionally, the capital expenditures incurred on an annual basis were to replace machinery at the end of their expected lifetime.

A capital budget is not only used to calculate the financial performance of a farming system but also to calculate the net movement of money through the farming business over time. Annexure B shows an example of a capital budget for a typical farm in the Western Rûens. The following calculation is used to determine the net movement of money for a farming business:

Net movement of money = Gross margin for all enterprises (annually) – fixed costs – external factor costs – capital expenditure

The net flow of money is used to calculate the IRR and NPV. The IRR and NPV are indicators of whole-farm profitability and can assist researchers in understanding the risk tolerance of a whole-farming system over time. To evaluate the financial indicators of changes to a typical farming system in the Western Rûens in real terms, future cash flows are discounted at a real interest rate. By assessing the financial implications of different production scenarios using the IRR and NPV, the effects of inflation, initial capital investments and the time required for changes to be implemented can be eliminated. The initial capital investment and the prices are similar as the “typical farm” and serve as a basis for the assessment of regenerative farming and conventional farming orientations. This can facilitate a relatively objective decision-making environment for farmers. The IRR indicates how much growth the whole-farm cash flow will generate over the chosen period in terms of the return made on the initial capital investment made. The NPV is used to determine the current value of future cash flows and is calculated by using a discounted interest rate defined as the weighted average cost of capital (WACC). Both the IRR and NPV are indicators of whole-farm profitability but can be used to assess different aspects of whole-farm profitability. The IRR is typically used to assess the financial impact of a change in farm strategy and the NPV is used to assess the impact of a potential production scenario on future cash flow (in real terms).

3.4.3.2 Cash flow budgets over multiple periods

When the financial feasibility of an investment is assessed, a cash-flow budget is useful in measuring the impact of borrowed capital and interest paid or earned (Hoffmann, 2010). A cash-flow budget is solely based on cash and interest amounts paid or earned on the bank balance. The interest rate is calculated based on a real interest rate as prices are assumed to be constant. The real interest rate is calculated using a nominal interest rate and the inflation rate. The equation below represents the formula used for this calculation (Hoffmann, 2010):

“Real interest rate = { [(nominal interest rate + 1) / (inflation rate + 1)] – 1 } %”

A cash-flow analysis can be useful to assess the financial implications of machinery procured or the short-term impact of an implemented crop rotation system on annual cash flow.

3.5 Scenario planning as an explorative tool in whole-farm budgeting

Regenerative farming practices are a relatively new concept to Southern Cape farming systems, the possible implementations and outcomes for the Western Rûens are numerous and risky in terms of future farm production decisions. Scenario planning is a tool that can be used to hypothetically assess a selection of the most likely financial implications of regenerative practices in the Western Rûens. According to Peterson *et al.,* (2003), scenario planning can be defined as:

“a systemic method for thinking creatively about possible complex and uncertain futures.”

When considering the financial implications that a change in farming practices might have on whole-farm profitability, scenario planning can be used to construct a framework for simulated changes. The simulated changes can be applied to the parameters, assumptions and inputs of a typical farm. In the context of this study, a scenario refers to a hypothetical change(s) made to a typical farming system in the Western Rûens. Apart from being hypothetical, scenarios can describe processes that are constantly subject to change and entail a sequence of events that endure push and pull factors that drive progress (Anastasi *et al.*, 2000). Scenarios are usually simulated for a fixed time and have a point of departure, in this case the typical farm under CA, and a final stage. Scenarios are thus well suited to the scope of this study which requires the simulation of hypothetical changes to a typical farming system.

To assess the financial implications of regenerative agriculture in the Western Rûens, an explorative process is required to generate potential production scenarios that are realistic relative to the current farming environment. Figure 16 places scenario planning in the first quadrant as a coping mechanism for decision making under high levels of uncertainty and a low level of control (Peterson *et al.,* 2003). The remaining coping mechanisms of adaptive management, hedging and optimal control, in the remaining three quadrants, are better suited conditions where high uncertainty and a lack of control are not synonymous in the decision-making environment. To ensure the validity of this thought process, participants in the discussion group were invited to suggest potential production scenarios based on their knowledge and past experiences. The importance of a multidisciplinary approach to the creation and validation of potential production scenarios was important within the scope of this study.

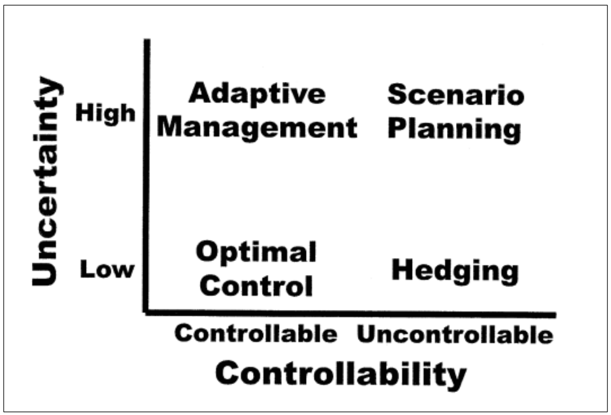

Figure 16 - Coping mechanisms for decisions to be made under conditions that can differ based on uncertainty and controllability. Source: Peterson *et al.* (2003).

Each of the scenarios assessed in this study are constructed based on expert knowledge and industry information surrounding the assumptions and parameters applicable to a typical farm in the Western Rûens. Each of the changes proposed within each scenario are implemented under the assumption that all other factors not explicitly mentioned were presumed to have stayed constant (*ceteris paribus*).

3.6 Conclusion

The general research aim is to explore the management and financial implications of adopting a regenerative farming orientation in cereal production systems in the Western Rûens. To achieve this, a budget model that can integrate regenerative farming principles and activities into the whole-farm system and subsequently express it as a financial outcome, is required. In Chapter 3, the theoretical concepts discussed in Chapter 2 were applied to the farm level and the thought processes that underpin the financial assessment of a typical farm in the Western Rûens were explained in detail.

This chapter consisted of five sections. In the first section, the geographical context of this study and the relevance of a soil regeneration trial in the Southern Cape were established. In the second section, typical farm theory was introduced as an explorative tool to simulate potential production scenarios on a typical farm in the Western Rûens. The third and fourth sections outlined the basic structure of a budget model and the functional role of a multidisciplinary discussion group in validating the assumptions and parameters of a multi-period whole-farm budget model. The chapter concluded with a discussion on how the financial indicators calculated in a whole-farm budget model can be used to assess various production scenarios surrounding future crop and animal production in the Southern Cape under regenerative farming practices.

In Chapter 4, the structure of a whole-farm budget model, described in this chapter, will be applied in detail to simulate a typical farm in the Western Rûens. Additionally, the various production scenarios relevant to assessing the financial implications of regenerative farming in the Southern Cape will be assessed on a whole-farm level.

Chapter 4: Results and findings

4 Introduction

To explore the management and financial implications of adopting a regenerative farming orientation in the Western Rûens, a whole-farm approach is constructed. In Chapter 3, the structure of a whole-farm budget model was discussed on a theoretical level and applied to a farm level using typical farm theory. The Rûens homogenous farming area and the soil regeneration trial currently underway in the Southern Cape were introduced and allocated contextual relevance to this study. Furthermore, the functional role of a multidisciplinary discussion group in the validation of the preliminary budget model constructed and the scenarios created were established. The use of scenario planning as an explorative thought process to generate potential production scenarios in the current farming environment was also introduced in Chapter 3.

The purpose of this chapter is to describe the actual values and calculations used to simulate a typical CA farm in the Western Rûens and to assess the financial implications of various potential production scenarios on a typical farm. This chapter consists of two sections. In the first section, the final budget model constructed in this study is explained in detail according to the assumptions, parameters and values validated during the discussion group held. In the second section, various changes to the typical farm are simulated using scenario planning. The simulated changes assess the financial implications of selected regenerative farming practices on future crop and livestock production in the Southern Cape.

4.1 A typical farm in the Western Rûens

Farming systems with two or more enterprises can become complex to simulate as there are numerous variables that need to be considered. The flow of information simulated in a multi-period whole-farm budget model is logical and synchronised from the input component to the output component. This synergistic flow of information facilitates an element of interactivity in the budget model, which is necessary to assess the financial implications of various changes to be made to a typical CA farm in the Western Rûens. In addition to being interactive, budget models allow for the integration of biological processes and the financial elements of the whole farming system. Both elements are relevant to this study as regenerative agriculture requires a mind shift in the management approach to improving soil health.

Using Microsoft Excel, a multi-period whole-farm budget model was constructed to mimic a typical farm in the Western Rûens. Each of the important components in the whole-farm budget model are discussed in detail in the following sections.

4.1.1 Farm description

The farm description outlines the biological and financial parameters of the farming system to be simulated. The farm description also ensures that the simulated outcome of the budget model is as close to reality as possible.

During the multidisciplinary group discussion, participants agreed to a typical farm in the Western Rûens of 1100 hectares in size and approximately situated between Swellendam and Bredasdorp in the Southern Cape. A typical farm would have a 65/35 crop/pasture (for livestock) ratio with 715 hectares available as arable land for cropping activities. The remainder of the farm is used for fixed improvements and indigenous Renosterveld vegetation to be utilised as extensive livestock grazing when pastures are not planted in the cropping system. Daily farm operations are overseen by the farm owner who along with eight labourers, all draws a monthly salary from the farming business. Fertile soil and dryland cropping conditions facilitate the stacking of seven enterprises, namely: canola, wheat, barley, oats, lupines, sheep and pastures.

In this study, pastures refer to winter and summer cover crops which may include a variety of plant species. The carrying capacity per SSU on the pastures grown is assumed 4.5 SSU per hectare of pasture. When deciding on a cover crop mix, farmers should ideally determine a mix that will maximise the desired outcome for their specific farming system (Smorenburg, 2020). For example, if a farmer wanted to increase the nitrogen levels in a field’s soil, a nitrogen fixing plant would be incorporated into the cover crop mix. Furthermore, the summer and winter cover crop mixes selected assist farmers with weed control by selecting broad leaf or grass varieties of plants. The cover crop mixes used in the final budget model are based on the mixes used in the soil regeneration trial discussed in Section 3.1.1.1.

Crops are rotated on an annual basis according to three predetermined crop rotation systems. A cropping schedule determines the sequence in which crops are rotated in each system, the length of each system and the amount of land allocated to each crop enterprise (Table 4.1). It is important to note that each of these parameters in a cropping schedule can vary, depending on the management approach of the farming system in question. The discussion group verified the crop rotation systems detailed in Table 4.1 to ensure that the cropping practices of a typical farm in the Western Rûens area were accurately represented. Additionally, the incorporation of cover crops as pastures in the crop rotation schedule was structured to maximise moisture retention in the soil, facilitate intensive grazing and the natural provision of soil nitrogen. Incorporating cover crops in a typical CA farm crop rotation system can encourage beneficial biological processes in the soil which can have a positive impact on cash crop yields the following year (Strauss, 2020b).

The land allocated to cropping activities was divided and allocated to a crop enterprise within each cropping system. Using the "DSUM" formula in Microsoft Excel, the total area allocated to each crop enterprise throughout all three systems was calculated in Table 4.1.

Table 4.1 – The crop rotation system length and land allocation per system (top) and the hectares allocated to each crop enterprise within the crop rotation system (bottom).

Crop rotation system length and land allocation											
	Crop	**Year**	**ha**		**Crop**	**Year**	**ha**		**Crop**	**Year**	**ha**
System 1	Pastures	1	14,30	System 2	Pastures	1	22,00	System 3	Pastures	1	20,43
	Pastures	2	14,30		Pastures	2	22,00		Pastures	2	20,43
	Pastures	3	14,30		Pastures	3	22,00		Pastures	3	20,43
	Pastures	4	14,30		Pastures	4	22,00		Pastures	4	20,43
	Pastures	5	14,30		Pastures	5	22,00		Pastures	5	20,43
	Wheat	6	14,30		Pastures	6	22,00		Pastures	6	20,43
	Barley	7	14,30		Wheat	7	22,00		Wheat	7	20,43
	Canola	8	14,30		Barley	8	22,00		Barley	8	20,43
	Wheat	9	14,30		Barley	9	22,00		Canola	9	20,43
	Barley	10	14,30		Canola	10	22,00		Wheat	10	20,43
					Wheat	11	22,00		Barley	11	20,43
					Barley	12	22,00		Lupins	12	20,43
					Oats	13	22,00		Wheat	13	20,43
									Barley	14	20,43
Total per system			**143**				**286**				**286**

Crop	**Total ha**
Canola	57
Wheat	134
Barley	156
Oats	22
Lupins	20
Pastures	326
Total cropping ha	**715**

Source: Own calculations.

Due to high land values, inconsistent cash flows and a high cost of maintaining farming activities, financing is often required to farm in a financially sustainable manner. The finance structure of a farming system can vary amongst farms and is relatively subjective. Considering this, discussion group participants gave their inputs on financing structures. The assumptions used in the budget model presented to the discussion group were taken from previous studies on farming systems in the Western Cape (Hoffmann, 2010). The capital required for the repayment of the farmland purchased was assumed to be 80% own capital and 20% externally financed. The medium-term capital structure for financing movable assets such as machinery also favoured the use of own capital at 60% and borrowed capital at 40%.

From a production perspective, allocating a financial value to the impact of an exogenous climatic factor such as annual rainfall on crop yields or livestock grazing is challenging. The amount and timing of annual rainfall is typically beyond a farmers control and can affect the whole farming system directly or indirectly. As a dryland cropping area, farming systems in the Southern Cape rely on consistent rainfall patterns. In the budget model, rainfall is incorporated as a determining factor in crop yield quantity and is subsequently a factor of whole-farm profitability. Revenue is then calculated based on the yield prediction made for good, fair or poor rainfall year. By allocating typical crop yield quantities to rainfall parameters, it is possible to incorporate the impact of annual rainfall on whole-farm profitability (Table 4.2). Using historic rainfall data collected for Tygerhoek Research Farm shown in Figure , the rainfall parameters in Table 4.2 were applied to the crop yields for each crop enterprise. The estimated crop yields in a good, fair and poor rainfall year were based on the experience and knowledge of discussion group participants. It should be noted that rainfall distribution during the growing season plays an important role, but a certain minimum can be considered a fair benchmark for this study.

Table 4.2 - Annual rainfall (mm) parameters according to yield potential (left) and the yield per crop in good, fair and poor rainfall (right).

Annual rainfall (mm) parameters				
Good	375	to	539	mm
Fair	251	to	374	mm
Poor	0	to	250	mm

Crop	Yield - ton/ha		
	Poor	Fair	Good
Canola	0,96	1,28	1,6
Wheat	1,74	2,32	2,9
Barley	1,8	2,4	3
Pastures	1,8	2,4	3
Oats	1,56	2,08	2,6
Lupins	0,84	1,12	1,4

Source: Own calculations.

4.1.2 Inventory

As discussed in Section 3.4.2.1, the inventory provides an indication of the assets and capital required to run farm activities on a medium to long-term basis. During the group discussion, participants assessed the assumptions made in the preliminary budget model regarding land, machinery (including implements), fixed improvements and livestock. The final values for each of these asset categories as validated by the discussion group participants are discussed in this section.

Based on the assumption that a mixed crop-livestock farm in the Western Rûens is worth R40 000 per hectare on average, the total land value of the typical farm was assumed to be R44 000 000. It should be noted that land prices in higher potential farming areas are significantly higher. The fixed improvements required for a typical farm are necessary for farm operations to take place and consist of housing, sheds, handling facilities for sheep, fencing and water supply infrastructure. The total value of the fixed improvements amounted to R1 593 000.

Machines that are key to crop and livestock activities on a farm include tractors, combine harvesters, vehicles, trailers and implements. The machines on a typical farm in the Western Rûens are assumed to have an expected life of 12 years and depreciate annually on a straight-line basis. Machines are sold at the end of their expected lifetime and sold at a fixed salvage value of 10% of the cost price. The replacement costs of all machinery and the salvage cost assumption were taken from the *Machinery Cost Guide for Western Cape Grain Producers* (Gregory, 2020). Machine replacements are planned in advance to avoid cash flow shortages within a given year. Annexure D shows an example of the machine replacement schedule used in this study. The red blocks in the schedule represent the years in which a machine is due to be replaced. The numbers represent the remaining years of the machines expected lifetime. When machines are replaced, a salvage value of 10% is calculated on the cost price of the machine and deducted from the cost of a new machine or implement.

Annexure C shows the full inventory for a typical farm in the Western Rûens. The total value of the machinery needed to run a typical farm is R16 368 221. Table 4.3 contains a summary of the machinery required on a typical farm in the Western Rûens. Tractors require the highest capital input in total but have a smaller value per unit, than combine harvesters.

Table 4.3 - Summary of the machinery on a typical farm in the Western Rûens.

Summary of the machinery on a typical farm in the Western Rûens		
Tractors	R	9 058 000,00
Combine Harvesters	R	3 800 000,00
Vehicles	R	863 300,00
Trailers	R	602 729,00
Implements	R	2 044 192,00
Total	**R**	**16 368 221,00**

Source: Own calculations.

As discussed in Section 2.1.2, by creating forward and backward linkages between crop and livestock enterprises, crop farmers in the Swartland and Overberg Rûens are able to improve their whole-farm cash flow with the production of commodities such as wool and mutton. Discussion group participants agreed to a flock size of 3 412 sheep to the value of R8 932 329.47 as representative of the Western Rûens homogenous farming area (Table 4.4).

The number of sheep kept on a typical farm were calculated by multiplying the carrying capacity (unit/ha) by the number of hectares available for pastures. Land allocated for extensive grazing is not considered in this calculation as the carrying capacity would be significantly lower and the expectation is made that sheep are not grazed extensively unless there are no pastures left to graze in the crop rotation. Additionally, the sheep numbers are assumed to be constant between years. This assumption is based on the expectation that in a dry year, the wider farming area is dry and few farmers will be able to feed more sheep. In a good rainfall year farmers retain sheep to increase their rate of livestock production (Hoffmann, 2020).

During the discussion, participants agreed that the carrying capacity for an adult ewe on a typical farm in the Western Rûens could be 4.5 ewes per hectare of pastures. The sheep flock numbers in Table 4.4 and the flock composition in Table 4.5 are primarily based on the carrying capacity of the farm for an adult ewe. The flock composition is determined using the ram to ewe ratio, replacement ewe percentage, weaning percentage, lambing percentage and old ewe percentage in relation to the carrying capacity of an adult ewe.

Table 4.4 - Sheep flock value for Dhone Merinos on a typical farm in the Western Rûens.

Sheep flock value			
	Count	**Value per head**	**Total value**
Rams	37	R 3 102,00	R 113 790,78
Ewes - Productive	1467	R 3 022,80	R 4 435 419,21
Old ewes for finishing and termination	220	R 3 619,00	R 796 535,44
Replacement ewes	367	R 3 022,80	R 1 108 854,80
Weaner lambs	1321	R 1 876,23	R 2 477 729,24
Total	**3412**		**R 8 932 329,47**

Source: Own calculations.

Table 4.5 - Sheep flock composition on a typical farm in the Western Rûens.

Sheep flock composition		
		SSU/ha
Ewes per Ram	40	
Replacement ewe percentage	20%	
Lambing percentage	115%	
Weaning percentage	105%	
Old ewes (as % of productive ewes)	15%	
Carrying Capacity (Dhonne Merino)	Ewes	4,5
	Rams	0,1
	Lambs	5,7

Source: Own calculations.

4.1.3 Fixed costs

Fixed costs are usually affected by time and not by the extent or output of farm activities. Costs such as labour, water rights and municipal taxes are predetermined costs that are incurred on an annual basis and do not change with the quantity of output units produced. The fixed costs for a specific farming system usually do not change but fixed costs can differ from farm to farm. The total fixed cost of a typical farm in the Western Rûens is estimated at R1 863 860. Each of the fixed cost items in Table 4.6 were accepted by discussion group participants as representative of a crop-livestock farming system in the Western Rûens homogenous area. All the fixed costs remain constant year on year throughout the 20-year period simulated.

Table 4.6 – Fixed costs for a typical farm in the Western Rûens.

Fixed costs			
Item	**Description**	**R/year**	
Permanent labour	8 Staff	R	583 253,00
Bank charges		R	28 655,00
Farm miscellaneous		R	417 472,00
Consultations		R	72 259,00
Fixed improvements		R	342 221,00
Electricity		R	324 000,00
Water rights		R	51 600,00
Municiple tax		R	6 000,00
Communication		R	2 400,00
Advance: Irrigation		R	6 000,00
Auditors fee		R	24 000,00
Insurance on assests		R	6 000,00
Total fixed cost		**R**	**1 863 860,00**

Source: Own calculations.

4.1.4 Gross production value and gross margin

In a whole-farm budget model, the gross margin is calculated by adding the gross margins of all the individual enterprises in the farming system. To calculate the gross margin of an individual enterprise, the variable costs (directly and non-directly allocated) associated with production are subtracted from the gross production value (GPV).

The GPV is essentially the revenue generated by an enterprise before any of the associated costs are subtracted. Revenue is calculated per hectare for each farm enterprise by determining the product of the market price per unit and the number of units produced. As discussed in Section 4.1.1, rainfall is a determining factor in crop yield quantity and thus impacts the revenue generated by crop enterprises.

The prices used to simulate the production activities of a typical farm in the Western Rûens were obtained from local and national agricultural businesses that render support services to the farming sector. The applicability of the information collected was verified during the group discussion and various changes were made in accordance with suggestions made by the participants.

Discussion group participants suggested the use of average historical prices for simulating future crop and animal production scenarios instead of spot prices. The use of an average historical price could marginally improve the accuracy of forecasted production scenarios based on the premise that future prices are more likely to fluctuate over time than to remain constant. For example, each year the mutton price can be influenced by factors such as exchange rate appreciation or supply and demand. Three- and five-year average prices were calculated and used to offset the effect of outlying market prices in the crop and livestock sectors. Considering the recent periods of external shocks such as the COVID-19 pandemic, recent drought and FMD outbreaks in parts of the country, the possibility of using average prices in this study became an imperative (BFAP, 2020).

The wool and mutton prices in Table 4.7 are based on historical price information between 2016 and 2020. The mutton prices for rams, ewes and lambs were “on the hook” weekly prices for A, B, C and lamb grades of mutton (RPO, 2020 and Cape Wools SA, 2020b). The wool clip of sheep was assumed to consist of 80% clean wool and 20% greasy wool. It was assumed that on a typical farm in the Western Rûens sheep are shorn every 8 months. An 8-month shearing cycle has a significant impact on the cash flow of a farm as there is less wool to be marketed in some years and more in other years. A wool production schedule was used to determine the years that would have two wool clips and those that would only have one. In the years with only one wool clip, the gross margin of the sheep enterprise was -R 3 985.51 per hectare and -R1 299 559.78 for the whole enterprise. In contrast, a year with two wool clips, the gross margin of the sheep enterprise is R385.57 per hectare and R125 722.74 for the whole sheep enterprise.

Table 4.7 - Mutton and wool price assumptions for a typical farm in the Western Rûens

Sheep enterprise price assumptions				
Mutton price (5-year average)	Rams	R	51,70	R/kg
	Productive ewes	R	54,96	R/kg
	Old ewes	R	51,70	R/kg
	Replacement ewes	R	54,96	R/kg
	Weaner lambs	R	69,49	R/kg
Wool price (5-year average)	Greasy wool price (5-year average)	R	103,64	R/kg
	Clean wool price (5-year average)	R	165,58	R/kg

Source: RPO (2020) and Cape Wools SA (2020b).

Table 4.8 shows the product prices for the Southern Cape. The final crop prices used by the researcher were calculated by averaging the net farm gate price for each commodity over a period of three years. The average crop prices calculated were assumed to remain constant year-on-year over the forecasted period.

Table 4.8 - Dryland crop prices in the Southern Cape between 2018 and 2020 (Net Farm Gate Price)

Dryland crop prices in the Southern Cape between 2018 and 2020 (Net Farm gate price)								
	2018/2019		2019/2020		2020/2021		**3-year Average**	
Canola (R/ton)	R	5 070,00	R	5 668,00	R	7 020,00	**R**	**5 919,33**
Wheat (R/ton)	R	3 087,00	R	3 762,00	R	4 019,00	**R**	**3 622,67**
Barley (R/ton)	R	3 084,00	R	3 837,00	R	4 031,00	**R**	**3 650,67**
Oats (R/ton)	R	2 900,00	R	3 139,00	R	3 497,00	**R**	**3 178,67**
Lupins (R/ton)	R	3 250,00	R	3 245,00	R	3 997,00	**R**	**3 497,33**

Source: Protein Research Foundation (2020).

Error! Reference source not found. shows the gross margin for each crop enterprise in a g ood, fair and poor rainfall year on a typical farm in the Western Rûens. The calculation of the annual gross margin for each crop enterprise in the budget model differs depending on two factors. Firstly, the crop yield quantities vary according to the predetermined yield allocated to good, fair and poor rainfall parameters (Section 4.1.1 and Table 4.2). Secondly, the crop rotation schedule shown in Annexure E stipulates the years that a specific crop should be planted and a gross margin generated. The crops to be planted in a specific year are represented by the number “1” in the green blocks of Annexure E. The blank blocks containing “0” indicate that the relevant crop is not planted that year. When a crop is scheduled to be planted, the gross margin for the enterprise will automatically be calculated according to a series of "If" statements previously entered into a separate spreadsheet in Excel. For example, in Annexure E, canola is scheduled to be planted in the year 2027. The corresponding spreadsheet allocated to the gross margin calculation for canola (refer to Annexure F) will reflect the line item values applicable in the year 2027.

No gross margin is calculated for the pasture enterprise in Table 4.9 as the cover crops grown remained within the boundaries of the farm either as mulch or grazing for sheep. The costs incurred for planting the cover crops are assumed to be absorbed by the indirect increases in subsequent cash crop yields and reduced expenditure on off-farm sheep feed costs.

Table 4.9 - Gross margin per crop enterprise for a typical farm in the Western Rûens.

Gross margin per crop enterprise for a typical farm in the Western Rûens						
	Poor		Fair		Good	
	R/ha	R/whole enterprise	R/ha	R/whole enterprise	R/ha	R/whole enterprise
Canola	R 1 712,73	R 97 160,16	R 4 317,23	R 244 910,45	R 6 921,74	R 392 660,31
Wheat	R 1 350,12	R 200 069,10	R 3 885,99	R 520 278,96	R 6 421,86	R 859 795,59
Barley	R 2 595,02	R 404 527,17	R 5 333,03	R 831 342,65	R 8 071,03	R 1 258 158,12
Pastures	R -	R -	R -	R -	R -	R -
Oats	R 62,17	R 3 145,87	R 1 715,08	R 86 783,04	R 3 367,99	R 170 420,20
Lupins	-R 1 095,20	-R 53 696,33	-R 115,95	-R 5 684,98	R 863,30	R 42 326,37

Source: Own calculations.

In Figure 174.1, the whole farm gross margin for the typical farm simulated was forecasted to increase, on average, by R45 951 per year over a 20-year period. In the first five time periods of Figure 17, the whole-farm gross margin remained constant as the crop rotation schedule[10] for the typical farm stipulated that only pastures were to be planted for the first five years.

[10] See Table 4.1 for the planned crop rotation schedule.

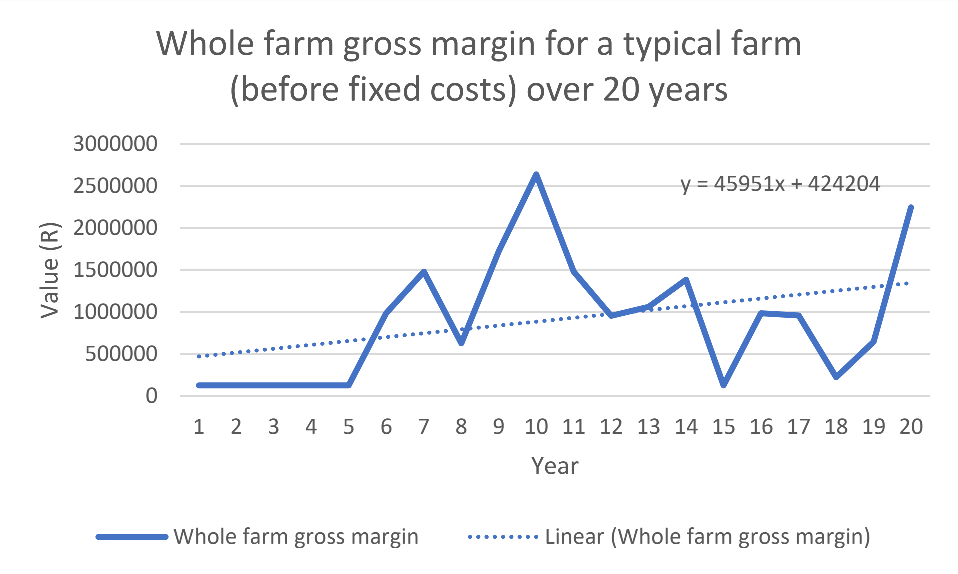

Figure 17 – Whole-farm gross margin for a typical farm (before fixed costs) over 20 years. Source: Own calculations.

In contrast to the fixed costs briefly discussed in Section 4.1.3, variable costs are directly influenced by changes in the quantity of outputs produced. The variable costs of an enterprise or a whole farm are calculated per unit to ensure that marginal cost changes can be accurately recorded and assessed. For example, the variable costs of canola in Table 4.10 are calculated per hectare and can then be multiplied by the number of hectares allocated to canola in the crop rotation system to attain the total variable cost for canola incurred by the whole farming system. Variable costs such as seed, fertiliser or weed management are directly allocated to canola production but costs such as fuel are not and merely serve as a usage guideline for planning purposes. A five-year average diesel price of R12.28/litre was calculated and used in determining fuel costs on a typical farm in the Western Rûens (DOE, 2020). The variable costs per enterprise in Table 4.10 were assumed to remain constant throughout the 20-year period simulated.

Table 4.10 – Variable costs for crop and sheep enterprises on a typical farm in the Western Rûens.

Variable costs for crops and sheep				
	Per ha		Allocated ha's	
Canola	R	6 100,79	R	346 097,70
Wheat	R	6 257,48	R	837 814,39
Barley	R	5 618,98	R	875 943,34
Pastures	R	2 347,23	R	765 360,50
Oats	R	4 896,55	R	107 724,18
Lupins	R	4 032,96	R	82 393,41
Sheep	R	7 316,54	R	5 202 571,54

Source: Own calculations.

4.1.5 Whole-farm profitability, cash flow and liquidity

For a farming system to remain financially sustainable, each of the enterprises contributing to whole-farm profitability need to be operated with the aim of generating a positive margin. A significant challenge in obtaining this goal is understanding how to create a balanced portfolio of on-farm enterprises that are also suited to the farmers risk appetite.

Whole-farm profitability is measured by the IRR and NPV. These indicators were calculated for a typical farm in the Western Rûens using the capital budget model shown in Annexure B. The IRR and NPV for the whole farming system over a period of 20 years was -3.22% and -R66 405 812.70 respectively. The nominal interest rate and the inflation rate used to calculate the IRR and NPV were calculated based on the 5-year average between 2016 and 2020 (Stats SA, 2020b and SARB, 2020). The average inflation rate used to calculate the NPV was 4.6% and the average nominal interest rate used to calculate the real interest rate was 9.60%. The real interest rate of 4.78% was calculated based on the formula given in Section 3.4.3.2. The IRR for a typical farm indicated a negative return on the initial investment made. The NPV became negative once the IRR percentage dropped eight percent below the real interest rate of 4.78%.

Crop-livestock farming systems typically have sporadic revenue streams as crops or livestock reach the market at different rates. Certain expenses such as labour, machinery payments or insurance, require monthly payments which need to be aligned with irregular farm income. The cash flow of a farm is thus an important planning tool for a farmer to avoid or anticipate months of cash shortages.

A cash-flow budget was included in the whole-farm budget model to assess the ability of the whole farming system to equate the incoming and outgoing cash flows. The farming system is assumed to have a starting cash balance of zero. Each year thereafter, the opening balance of each period is equal to the closing balance of the previous year. The inflow and outflow are then balanced and interest is paid or earned on the cash surplus/deficit. Included in the cash outflow are annual loan repayments due, regarding a portion of the investment requirement funded with borrowed money. Once the interest amounts on the remaining cash balance are calculated, the closing balance is determined. The closing bank balance of the typical farm simulated in this study was progressively negative over a period of 20 years. Machinery replacements and high fixed costs are important factors that likely caused this trend.

4.2 Scenario simulation and assessment

The aim of this section is to simulate potential production scenarios that a typical farm in the Western Rûens might undergo during a transition from a CA oriented farming system to a regenerative orientated farming system. The financial implications of these scenarios are assessed on a whole-farm level using a multi-period budget model.

In Section 3.5, scenario planning was introduced as an explorative planning tool to apply to whole-farm budgeting. Scenario planning is applied by hypothetically assessing a selection of the most likely production possibilities regarding regenerative practices in the Western Rûens. Each of the changes proposed within each scenario are implemented under the assumption that all other factors are constant (*ceteris paribus*).

4.2.1 Scenario selection

With limited research on regenerative farming in the Southern Cape to draw from, the scenarios chosen for this study were based on the knowledge and experience of the discussion group participants. The participants identified four scenarios to consider as a point of departure in the transition from a typical CA farming system to a regenerative system. As discussed in Section 2.2.1, regenerative agriculture practices share selected foundational principles with other farming practices such as CA but incorporate a greater emphasis on biomimicry than external inputs. Considering this, participants suggested that a gradual reduction in the annual amount of N applied, a change in livestock management, and machinery adjustments were three key areas that could have financial implications on future crop and livestock production on a typical CA farm in the Western Rûens. A fourth scenario was implemented to simultaneously assess the financial implications of each of the most profitable preceding production scenarios.

The essence and relevance of each of these four scenarios are present on a national and global level. In addition to long-term exchange rate depreciation relative to the US Dollar, the agricultural input costs in South Africa are forecasted to increase significantly over the next 10 years with Brent crude oil prices possibly surpassing $80 per barrel (BFAP, 2020 and Figure 4.2). The combination of a depreciating exchange rate (R/$) and a higher oil price can result in higher fuel costs which can in turn result in higher input costs on a farm level. Among other factors, the price of farm inputs is impacted by changes in the Brent crude oil price due to higher transport and manufacturing costs required throughout the value chain. The national nominal input costs trends are shown in Figure . Relative to the base year of 2008/09, maintenance, pesticides, fertilisers and seed underwent significant increases in nominal input costs. The maintenance and pesticide cost trends incurred the largest increase of 200~250 base points during this period while seed and fertilisers showed an increase of at least 100~130 base points. The fuel input cost initially decreased from the base year to 2009/10 but is expected to gradually increase in accordance with the Brent crude oil trend observed in Figure 4.2. With regards to the above trends, each of the scenarios tested were assessed under the assumption of *ceteris paribus* conditions.

In the current regenerative trial underway in the Southern Cape (discussed in Section 3.1.1.1.), a period of three years was allocated as a "transitional period" to allow for a gradual change to take place in the soil structure and to gradually reduce the use of inorganic inputs before implementing fully regenerative farming practices. The success of a transitional period is still to be scientifically confirmed but could potentially be a necessary step in the transition from CA-base farming systems to purely regenerative systems (Strauss, 2020b). Additionally, regenerative farming practices implemented under regenerative principles often involve the stacking of enterprises to attain a balance between mimicking biological processes and maintaining whole-farm profitability.

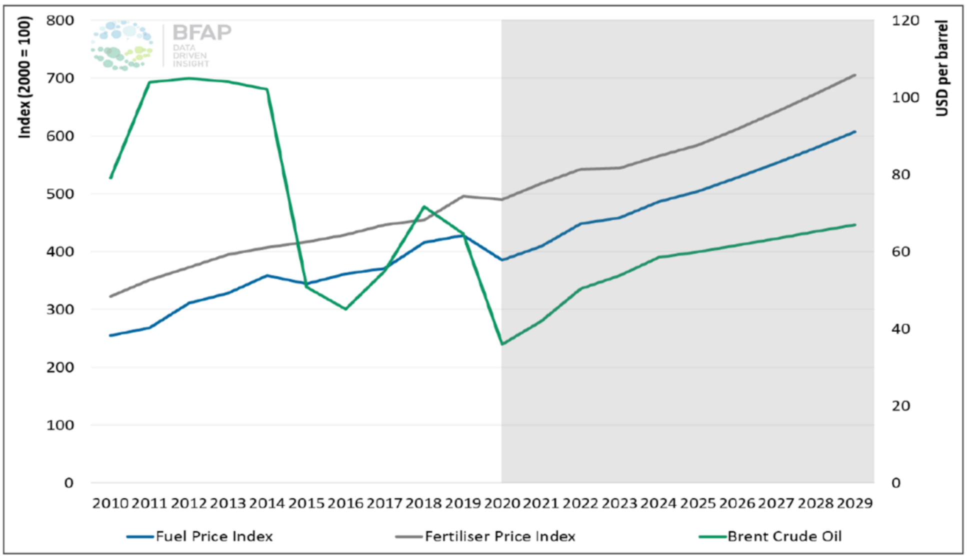

Figure 4.2 – Oil price assumption and input cost implication. Source: BFAP (2020).

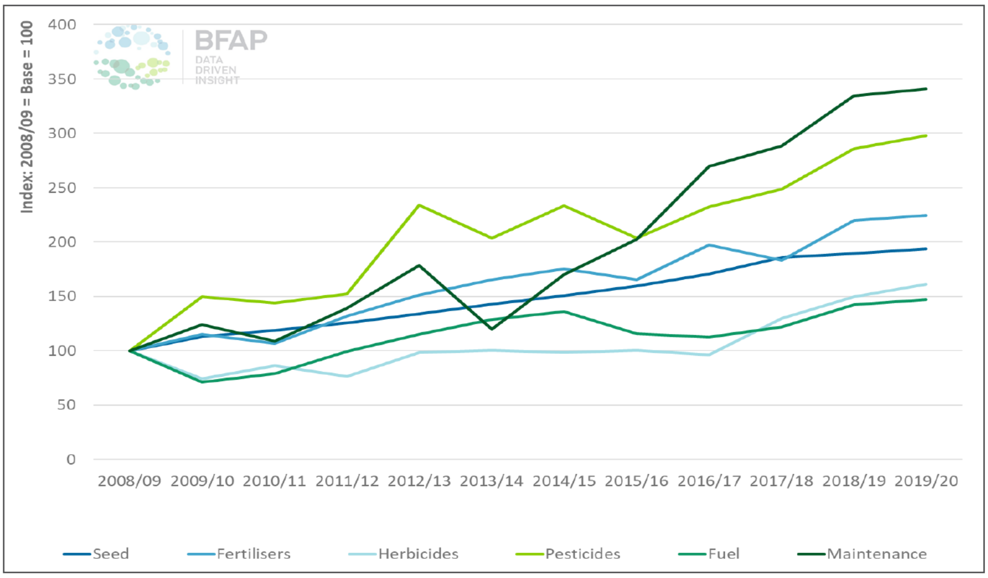

Figure 4.3 – Nominal input costs trends in South Africa between 2008/09 and 2019/20. Source: BFAP (2020).

By using scenario planning, a typical farms risk tolerance is assessed in terms of whole farm profitability. Scenario planning can help farmers and researchers to assess the financial implications of changes needed for the shift from a typical farming system in the Western Rûens to a purely regenerative farming system.

4.2.2 Scenario 1: Reduced N applications over time

The extent that rising input costs have on the farm level were empirically established in Section 4.2.1. In the typical farming system simulated in this study, fertiliser was the most expensive directly allocated cost for each crop enterprise. The impact of improved soil health managed under regenerative practices has yet to be formally assessed in the Southern Cape. Based on previous research (Lacanne *et al*., 2018 and Figure 2.3), there is a possibility that after a period of adjustment, a farming system in the Southern Cape could endure a gradual reduction in inorganic inputs. However, it is important to note that a reduction in inorganic inputs such as nitrogen (N) should be implemented gradually as a sudden reduction could result in short-term cash flow issues. Based on the results determined in Figure 2.3, the biological benefits of regenerative farming practices could in the long-term, potentially lead to similar or increased yields relative to conventional or CA-based farms but with a lower input cost

The principles of regenerative agriculture (Figure 2.1) are focused on the creation of balance between the biological factors within the agro-ecological environment. Plant diversity and soil health are important in creating the foundational structures for the underlying synergies necessary in creating this collaboration. Cover crops consisting of perennial plants and N-fixing legumes are key in initiating these synergies ahead of the subsequent collaboration generated. As discussed in Section 2.3.2.1, cover crops increase SOM and as a result have a beneficial impact on soil microbial activity, nutrient cycling and soil water retention. Cover crops mixes incorporating legumes can serve as either a catch crop to stop N leaching in fallow years or as a soil N source for a cash crop planted in succession within a crop rotation system (Peyrard *et al.*, 2016; Muñoz *et al.*, 2014 and Jani *et al.*, 2015).

The farms in foreign countries where regenerative agriculture is successfully implemented typically receive good summer rainfall and snow cover in the winter. These factors tend to facilitate better crop production conditions and enable the planting of cover crops in the winter months. Winter cereal production in the Southern Cape is subject to winter rainfall and hot, dry summers, which tend to result in lower production yields relative to areas with summer rainfall and snow cover in the winter (Strauss, 2020b). The addition of a summer cover crop enterprise to a typical farming system in the Western Rûens could increase the availability of grazing for sheep in summer months and keep living roots in the soil throughout the year. However, the plant growth in hot and dry summer conditions can remove moisture from the soil necessary for the sustained growth of subsequent cash crops in a drier year (Du Toit, 2020).

In this scenario, the assumption is made that by including legumes and perennial cover crops in the crop rotation schedule, the N-levels in the soil increase and gradually reduce the need for added inorganic N. Sheep are grazed under high density grazing on the cover crops[11] which were planted in accordance with the crop rotation schedule in Table 4.1 and Annexure E. The consecutive planting of pastures (cover crops) ensures that there are at least five years of living roots in the soil before cash crops are planted. This should also allow for the gradual process of soil regeneration to begin. This period of transition before cash crops are planted facilitates the hypothetical conditions necessary to assess the possibilities surrounding the decreased dependency on external inputs such as N.

The reduction in added inorganic N was gradually implemented to reduce the negative financial effects of reduced yields in the short-term. Annual crop yields are assumed to remain constant other than the predetermined change in yield in poor, fair and good rainfall years. As discussed in Section 4.1.4, no gross margin was calculated for the pasture enterprise as the cover crops grown remain within the boundaries of the farm either as mulch or additional

[11] The financial implications of an increase in carrying capacity resulting from the inclusion of summer and winter cover crops in a typical farming system, will be assessed in Section 4.2.3.

grazing for sheep. The cost incurred for planting winter cover crops, and the addition of a summer cover crop, are assumed to be absorbed by indirect increases in subsequent yields and reduced off-farm sheep feed costs.

Participants in the discussion group agreed that under regenerative farming practices, a scenario regarding a reduction in the amount of N applied per hectare over time on a typical farm in the Western Rûens could be plausible. As an explorative study, there is no pre-determined guideline of changes in N quantities to be simulated, however, to assess the financial tolerance of a typical farm in the Western Rûens over time, the changes in the quantity of N simulated were in increments of 10 percentage points. Based on the above-mentioned assumptions, the quantity of synthetic N applied in the fertilizer mix was changed by 10%, 20% and 30% after an initial transitional period of 3 years where the amount of N was held constant. It is important to note that regenerative farming practices require time and location specific knowledge that is built up over a period of time and via a process of trial and error. The impact of reduced N as a component of the fertilizer mix applied is measured using the IRR and NPV.

Each cash crop enterprise was allocated the relevant amount of fertilizer per hectare based on study group data previously collected in the Southern Cape (Gregory, 2020). The fertilizer cost structure applied to each crop enterprise comprised of N, phosphorus, potassium and lime. The spot price assumptions (per kg) of each fertilizer component were R14.36, R34.42, R14.45 and R153.00 respectively. No fertilizer is applied to winter or summer cover crops. The cost of fertilizer per hectare was calculated by determining the product of the quantities allocated to each component of fertiliser by the unit price incurred during procurement. A reduction or increase in external inputs has a direct impact on the whole-farm cash flow and profitability which necessitated the assessment of both an increase and decrease in the amount of N to be applied.

In Table 4.11, the annual change in N applied (kg/ha) is presented in the first column. The annual change in the amount of N was calculated on the total cost of the fertilizer applied per hectare in the previous year. Columns two and three represent the IRR and NPV of the typical farm simulated according to its “initial state” before any changes in the amount of N were imposed. The “subsequent state” represents the typical farm after the amount of N added to the fertilizer mix was changed. The impact of changes in the quantity of N applied on whole-farm profitability in columns four to seven provide an indication of how tolerant the typical farming system is to changes in N as an external input cost.

According to the results in Table 4.11, a 10% decrease in the annual quantity of N applied is expected to be the most profitable with regards to the IRR and NPV of the typical farm with increases of 4.43% and 0.87% respectively. Any other annual changes made within the above-mentioned parameters to the annual amount of N applied, had an expected negative effect on whole-farm profitability. This expected result supports the notion that on the typical farm simulated in this study, a reduction in the amount of N applied should be gradual and no more than 10%. A 10%, 20% and 30% increase in the annual amount of N applied would result in a significant decrease in the IRR of at least 13.65% and at most 17.57% over a period of 20 years (Table 4.11). The typical farm would thus be financially tolerant of a 10% decrease in the annual amount of N applied but would not be tolerant of any other change within the given parameters. From the parameters used to assess the financial implications of an increase in the annual amount of N applied, a 10% change would have the least significant impact on the IRR and NPV over 20 years.

Table 4.11 - Scenario 1: The effect of changes in N applied (kg/ha) on whole-farm profitability.

Scenario 1: The effect of changes in N applied (kg/ha) on whole farm profitability.						
	Initial state		**Subsequent state**			
Annual change in N applied (kg/ha)	*IRR*	*NPV*	*IRR*	*% Δ in IRR*	*NPV*	*% Δ in NPV*
10% ↓	-3,22%	-R 66 405 812,70	-3,08%	4,43%	-R 65 827 249,78	0,87%
10% ↑	-3,22%	-R 66 405 812,70	-3,66%	-13,65%	-R 67 769 463,50	-2,05%
20% ↓	-3,22%	-R 66 405 812,70	-3,47%	-7,82%	-R 67 094 534,91	-1,04%
20% ↑	-3,22%	-R 66 405 812,70	-3,72%	-15,61%	-R 67 994 439,70	-2,39%
30% ↓	-3,22%	-R 66 405 812,70	-3,41%	-5,89%	-R 66 869 558,71	-0,70%
30% ↑	-3,22%	-R 66 405 812,70	-3,79%	-17,57%	-R 68 219 415,90	-2,73%

Source: Own calculations.

4.2.3 Scenario 2: Livestock carrying capacity, feed and crop/livestock ratio

Animals are an important component in regenerative farming systems (Strauss, 2020b and Figure 2.1). Animals are considered beneficial within the agro-ecological environment as they play a role in the cycling of nutrients, farm cash flow and the preparation of fields for cash crops such as barley, wheat or canola to be planted. A transitional period of three years from CA-based practices to regenerative practices was not applied to the sheep enterprise as the pastures (cover crops) were planted from the start of the 20-year period simulated. In this scenario, the financial implications of four changes made to the sheep enterprise on a typical farm in the Western Rûens will be simulated. The changes are as follows:

- Change in carrying capacity (Scenario 2.1)
- Sliding feed scale (Scenario 2.2)
- Sliding feed scale and change in carrying capacity (Scenario 2.3)
- Change in the crop/livestock ratio (Scenario 2.4)

Regenerative farming practices are phased in over time and changes are implemented on a need's basis according to the basic principles discussed in Section 2.2.1. Considering this, Scenarios 2.1 and 2.2 will be assessed both individually and simultaneously in Scenario 2.3 to simulate the financial implications of a gradual change in the livestock management approach. Furthermore, changes in the crop/livestock ratio will be assessed to simulate the financial implications of accommodating high-density grazing through increases in the hectares of pastures planted.

Various ideas on animal production under regenerative farming were discussed during the meeting until consensus was reached. It was decided that under the assumption of a summer and winter cover crop being planted and managed under high-density grazing, the carrying capacity of a typical farm could gradually be increased. With limited information on high density grazing of winter and summer cover crops under regenerative farming practices in the Western Rûens, discussion participants were asked to suggest an increase in carrying capacity based on their personal experience and expert knowledge. The suggested change in carrying capacity was tested under an incremental increase of 1 SSU/ha from an initial 4.5 (SSU/ha) to a final number of 7.5 (SSU/ha). The incremental increases in the carrying capacity per hectare directly impacts the number of sheep kept on the farm.

The effect of a change in carrying capacity on the whole-farm profitability over time, under regenerative practices, were assessed in Scenario 2.1 (Table 4.12). The first incremental increase in carrying capacity from 4.5 to 5.5 SSU/ha resulted in an expected increase in IRR of 4.17% and a decrease of 1.82% in NPV. The contrasting impacts of the increase in the carrying capacity indicated that the movable assets of the farm increased the ability of the farm to cover the applicable liabilities but decreased long term cash flow in conjunction with the financial movements of the cropping enterprises. Similarly, the following two increments from 5.5 to 7.5 SSU/ha resulted in a similar impact on the whole farm IRR and NPV relative to the first increase from 4.5 to 5.5 SSU/ha. However, the percentage increase in IRR from 5.5 to 6.5 SSU/ha was 96% bigger than the percentage increase from 6.5 to 7.5 SSU/ha at 46%. A similar trend was observed for the percentage change in NPV.

The large difference in percentage changes in the IRR and NPV from the second and third incremental changes, support the notion that an increase in carrying capacity should be implemented gradually. Ideally, within the time of 20 years, the carrying capacity should only be increased by 1 SSU/ha under the above-mentioned conditions. This would eliminate the possibility of increasing the IRR and NPV at a decreasing rate, as would be the case with an increase to 7.5 SSU/ha.

Table 4.12 - Scenario 2.1: Change in carrying capacity.

Scenario 2.1: Change in carrying capacity						
Initial state		**Subsequent state**				
IRR	*NPV*	*Carrying capacity (SSU/ha)*	*IRR*	*%Δ in IRR*	*NPV*	*%Δ in NPV*
-3,22%	-R 66 405 812,70	5,5	-3,09%	4,17%	-R 67 617 663,46	-1,82%
-3,22%	-R 66 405 812,70	6,5	-2,96%	8,17%	-R 68 829 514,21	-3,65%
-3,22%	-R 66 405 812,70	7,5	-2,84%	11,95%	-R 70 041 364,97	-5,47%

Source: Own calculations.

In Scenario 2.2, a sliding feeding scale was imposed on the directly allocated feed costs incurred by the typical farm simulated in this study. The concept of a feeding scale is based on the foundation that in dryland cropping regions, rainfall has an impact on the sustained growth of plants and therefore on pastures. Furthermore, in a poor rainfall year, more feed is generally required to sustain a sheep than in a good or fair rainfall year. The increased feed requirement directly impacts the gross margin of a sheep enterprise due to the change in the amount of money spent on the feed requirements applicable in a poor, fair and good year. The feed cost in a fair and good year was calculated at 80% and 60% of the feed cost in a poor year (100%). This assumption was based on the notion that in a fair and good rainfall year, the amount of off-farm concentrates and roughage needed are lower than in a poor rainfall year. Similarly, the assumption is made that the cost to make on-farm concentrates and roughage would increase proportionately relative to the reduction in procured feed. This is due to an increased cost to process the higher quantities of on-farm pasture material.

In this scenario the carrying capacity is assumed to remain constant at 4.5 SSU/ha throughout the 20 years simulated. Sheep numbers are assumed to be constant during a good rainfall year. Farmers prefer not to sell sheep to focus on increasing production and in a poor rainfall year farmers do not opt to take on the financial risk of buying and sustaining more sheep. The sliding feed scale implemented in Table 4.13 positively impacts on whole-farm profitability with a 37.50% increase in IRR and a 10.55% increase in NPV.

Table 4.13 - Scenario 2.2: Sliding feed scale.

Scenario 2.2: Sliding feed scale					
Initial state		**Subsequent state**			
IRR	*NPV*	*IRR*	*%Δ in IRR*	*NPV*	*%Δ in NPV*
-3,22%	-R 66 405 812,70	-2,01%	37,50%	-R 59 403 293,79	10,55%

Source: Own calculations.

The financial implications of implementing a sliding feeding scale and an increase carrying capacity were assessed in Scenario 2.3. The results are shown in Table 4.14 . The initial state of the typical farm was based on a carrying capacity of 4.5 SSU/ha. An increase in carrying capacity from the initial state to 7.5 SSU/ha in the subsequent state had the most positive impact on whole-farm profitability. However, the percentage increase from 4.5 to 5.5 SSU/ha was significantly higher (48%) than the subsequent increases from 5.5 to 6.5 SSU/ha (22%) and 6.5 to 7.5 SSU/ha (17%). In a similar fashion to Scenario 2.2, an increase in carrying capacity by more than 1 SSU/ha would result in an increasing IRR and NPV at a decreasing rate. In summary, the simultaneous implementation of an increase of 1 SSU/ha in carrying capacity and the implementation of a sliding feed scale resulted in a higher increase in whole-farm profitability relative to Scenarios 2.1 and 2.2 being implemented individually.

Table 4.14 - Scenario 2.3: Sliding feed scale and carrying capacity.

Scenario 2.3: Sliding feed scale and carrying capacity						
Initial state		**Subsequent state**				
IRR	*NPV*	*Carrying capacity (SSU/ha)*	*IRR*	*%Δ in IRR*	*NPV*	*%Δ in NPV*
-3,22%	-R 66 405 812,70	5,5	-1,65%	48,83%	-R 59 059 029,23	11,06%
-3,22%	-R 66 405 812,70	6,5	-1,30%	59,54%	-R 58 714 764,67	11,58%
-3,22%	-R 66 405 812,70	7,5	-0,98%	69,69%	-R 58 370 500,11	12,10%

Source: Own calculations.

In Scenario 2.4, changes in the crop/livestock ratio were assessed to simulate the financial implications of accommodating a high-density grazing livestock management approach through increases in the hectares of pastures planted. Additionally, in a regenerative farming system, the stacking of on farm enterprises is encouraged.

The crop/livestock ratios on typical farms in the Overberg area remain relatively constant but can differ in certain instances (Du Toit, 2020). Crop/livestock ratios in this area are usually kept constant due to increasingly unpredictable rainfall patterns making it difficult for farmers to make drastic seasonal changes. To address the risk of cash flow shortages in a dry cropping year, the sheep component of a crop-livestock farm can be increased. An increase in the sheep component of a farm provides the option of avoiding additional feed costs through selling sheep in drier years and using the money to create regular cash flow throughout the year. According to study group data collected by a reputable business in the local farming industry, a typical farm in the Western Rûens operates using a 65/35 crop/livestock ratio (Gregory, 2020).

In Table 4.15, various crop/livestock ratios were simulated to assess the impact of each change on whole-farm profitability. Assuming a carrying capacity of 4.5 SSU/ha in the initial state, a crop/livestock ratio of 70/30 had the most significant positive impact on the whole-farm IRR and NPV over a twenty year period with a 92% increase in the IRR and a 17.50% increase in NPV. Regardless of the extent to which the simulated changes in the crop/livestock ratio affected the typical farm, the IRR and NPV in the subsequent state, in each instance, were significantly higher than the IRR and NPV of the typical farm in its initial state (65/35).

Table 4.15 - Scenario 2.4: Change in crop/livestock ratio.

Scenario 2.4: Change in the crop/livestock ratio						
Initial state		**Subsequent state**				
IRR	*NPV*	*Crop/livestock ratio*	*IRR*	*%Δ in IRR*	*NPV*	*%Δ in NPV*
-3,22%	-R 66 405 812,70	70/30	-0,24%	92,56%	-R 54 784 657,69	17,50%
-3,22%	-R 66 405 812,70	60/40	-0,84%	73,89%	-R 56 481 121,99	14,95%
-3,22%	-R 66 405 812,70	50/50	-1,48%	53,93%	-R 58 177 586,28	12,39%
-3,22%	-R 66 405 812,70	40/60	-2,17%	32,56%	-R 59 874 050,58	9,84%
-3,22%	-R 66 405 812,70	30/70	-2,91%	9,63%	-R 61 570 514,87	7,28%

Source: Own calculations.

4.2.4 Scenario 3: Changes in machinery

Cultivation practices associated with cropping systems in the Southern Cape rely on machinery to generate a revenue stream. Considering this, building up an inventory of the appropriate machines for a specific farming environment and field management approach is pertinent.

The typical farm in the Western Rûens utilises minimum or no-till equipment that are suitable for the implementation of CA practices. During the group discussion, participants agreed that the inventory list in Annexure C was representative of a typical farm in the Western Rûens, but minor changes were required to make the transition to regenerative practices. Participants suggested that the no-till seed drill should be discontinued and replaced at the end of its expected lifetime with a disk planter. The thin gap created and direct seeding action of a disk planter is less disruptive on the soil surface and more conducive to a homogenous growing environment by retaining soil moisture and structure. Furthermore, a roller/crimper was recommended as an addition to the existing inventory and an alternative to artificially terminating cover crops. The use of herbicides to terminate cover crops is permitted under CA principles, but to make the transition to a more regenerative farming system, a roller crimper was said to be more suitable.

In this scenario, the inventory of the typical farm in its initial state was adapted to accommodate the above-mentioned changes to machinery made by discussion group participants. The no-till seed drill was sold at the end of its expected lifetime and a 10% salvage value was earned from the sale and it was not replaced with another. In the same year, a disk planter was procured and the cost price incurred by the farm was reduced by the salvage value earned on the no-till seed drill.

The effect of the above-mentioned changes in machinery on whole farm profitability is given in Table 4.16. The IRR decreased by 13.86% and the NPV decreased by 4.34% indicating that over a period of 20 years, the applicable changes in machinery would have a negative effect on whole-farm profitability.

Table 4.16 - Scenario 3: Changes in machinery.

Scenario 3: Changes in machinery					
Initial state		**Subsequent state**			
IRR	NPV	IRR	%Δ in IRR	NPV	%Δ in NPV
-3,22%	-R 66 405 812,70	-3,67%	-13,86%	-R 69 284 785,43	-4,34%

Source: Own calculations.

4.2.5 Scenario 4: Scenarios 1 to 3 combined

The aim of this study is not to accurately define the financial implications of applying a purely regenerative orientation to a typical farming system in the Western Rûens. It is rather to explore and simulate the financial implications of selected changes to a typical farming system under CA practices. Considering this, the purpose of the following scenario is to assess the financial implications of a combination of the selected changes that were simulated from Section 4.2.2 to 4.2.4.

Profitability is often the goal of selected farming systems but sustained profitability is a standard requirement in many others. While various changes were simulated in scenarios 1 to 3, only one change per scenario can be simultaneously entered into the budget model built for this study. With sustained profitability as an end goal for the typical farm in the Western Rûens, the most profitable outcomes determined for each production scenario were simultaneously simulated and the results given in Table 4.17. To incorporate an aspect of each scenario, the recommended changes in machinery were implemented in this scenario regardless of the effect on whole-farm profitability. The most profitable outcomes simulated were as follows:

- An annual reduction of 10% in the amount of N applied.
- A carrying capacity of 5.5 SSU/ha.
- A sliding feed scale.
- Changes in machinery
- A crop/livestock ratio of 70/30.

Each of the above-mentioned changes was simultaneously entered into the constructed budget model. The financial implications of these changes on whole-farm profitability are shown in Table 4.17 and the impact of the changes on the whole-farm gross margin are graphically illustrated in Figure . The above-mentioned changes resulted in a 28% increase in the IRR and a 3.09% increase in the NPV of the typical farm simulated for this study. Additionally, in accordance with the increase in the whole-farm NPV, the gross margin of the subsequent state of the typical farm was significantly higher than the initial state for the duration of the 20-year period simulated.

Table 4.17 - Scenario 4: Scenario 1, 2 and 3 combined.

Scenario 4: Scenario 1, 2 and 3 combined					
Initial state		**Subsequent state**			
IRR	NPV	IRR	%Δ in IRR	NPV	%Δ in NPV
-3,22%	-R66 405 812,70	-2,29%	28,83%	-R64 372 818,85	3,06%

Source: Own calculations.

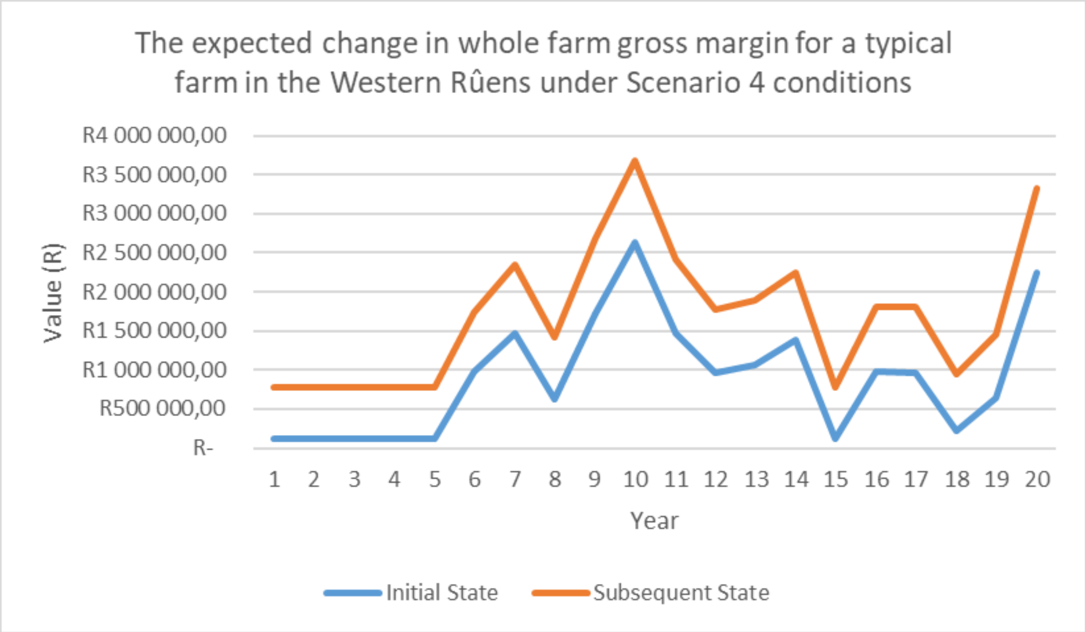

Figure 4.4 - The expected change in whole-farm gross margin for a typical farm in the Western Rûens under Scenario 4 conditions. Source: Own calculations.

4.3 Conclusion

The main aim of this study was to explore the expected implications of adopting a regenerative farming orientation to a winter cereal crop production farm in the Western Rûens. For this purpose, a whole-farm budget model was constructed according to a systems approach, allowing for the integration of the various facets of the farming systems and orientations. The design was done in a participatory manner and included the inputs from various experts. In this chapter, the final values and calculations used to simulate a typical CA farm in the Western Rûens were discussed in detail and used to assess the financial implications of various changes made in potential production scenarios on a typical farm, if regenerative farming practices were to be implemented.

In the first section, the final budget model used in this study was explained in detail based on the assumptions, parameters and values validated during the group discussion. The typical farm simulated, returned an expected IRR of -3.22% and an NPV of -R66 405 812.70. In the second section, various changes were made to the typical farm simulated using scenario planning and the results were used to assess the financial implications of purely regenerative farming practices on future crop and animal production in the Southern Cape. Discussion group participants identified four scenarios that could be considered as a point of departure in the transition from a typical CA farming system to a regenerative farming system. An annual reduction of 10% in the amount of N applied, a carrying capacity of 5.5 SSU/ha, a sliding feed scale and a crop/livestock ratio of 70/30 were the most profitable changes made to the typical farm over a period of 20 years. While each of these changes had positive financial implications on future crop and livestock production on a typical CA farm in the Western Rûens, changes made to the machine inventory had a negative effect on whole-farm profitability. A fourth scenario was considered to simultaneously assess the financial implications of each of the most profitable preceding production scenarios. The cumulative changes made to the typical farming system had a positive effect on whole-farm profitability. The IRR and NPV in the subsequent state of the typical farm were -2.29% and -R64 372 818.85 respectively.

Chapter 5: Conclusions, Summary and Recommendations

5.1 Conclusions

Rain-fed crop production relies on seasonal rain and more specifically on the rainfall distribution within the growing season. Increasingly irregular rainfall patterns, extended droughts and flooding require traditional farming systems to adapt accordingly. The transition to climate resilient food production will take time and will likely require farmers to overcome the barriers to adopting alternative agricultural practices. Timeous planning for climatic risk, particularly in mixed farming systems, could become imperative in future. Furthermore, agro-ecologically based farming systems may require a more holistic view of financial assessment that inherently includes an element of climatic risk assessment.

Regenerative agriculture shares selected foundational principles with other farming practices such as conservation agriculture (CA) but incorporates a greater emphasis on biomimicry than external inputs. The first three principles of regenerative agriculture concerning soil disturbance, soil cover and plant diversity are common CA principles but the remaining principles focus on internal inputs in the form of biomimicry and soil functions. Regenerative farming systems typically include one or more animal types, the maintenance of living roots in the soil during the year and ensuring that the cropping system implemented improves soil health in the long term. Furthermore, regenerative practices are not an “overnight” solution to the issues faced by producers and can take time to rebuild and create synergies in an agro-ecosystem. The emergence and progression of regenerative thinking will likely prove valuable in the design of farming systems in future.

In the lower lying areas of the Western Cape, fertile but shallow soils combined with wet winters and hot, dry summers form a suitable farming environment for the dryland crop production of winter cereals, legumes, oilseeds and livestock. Farmers in these areas often combine dryland crop and livestock production activities to create complementarity and diversity within their farming systems. The current farming environment for crop and livestock farmers in the Southern Cape may raise a few concerns for the introduction of an alternative farming system such as regenerative agriculture. Firstly, Southern Cape farmers may already be implementing conservation orientated farming systems that inherently employ cover crops and many farmers may lack clarity on the difference between the two practices. As a Mediterranean (winter rainfall) rain-fed cropping area, inconsistent weather patterns also increase the level of uncertainty in the farmer decision-making environment. This in turn diminishes a farmer's appetite for the risks associated with the adoption of new farming systems.

Simulation tools such as budgeting can help farmers manage the risks imposed on their businesses by simulating the effects that changes in exogenous and endogenous factors may have on the farming environment. To maintain a balance between these factors, farmers must be aware of the farm parameters that typically inhibit and expand production activities. In this regard, decision-making is arguably the most important element of a whole-farm approach to farming.

Farming systems are idiosyncratic, but there can be similarities in production conditions within a relatively homogenous farming area. Factors such as temperature, soil type and rainfall can be homogenous within a geographic area and allow for assumptions to be made regarding various farm input and output requirements. The budget model applied to this study was constructed to represent a typical whole-farm system over a period of 20 years. This was achieved using a computer-based spreadsheet programme called Microsoft Excel. Computerised spreadsheet programs are well suited to simulate farm systems as each enterprise or component of the farming system can be individually assessed or integrated into the whole-farm system. Budget models are structured to be flexible and interactive to allow for production and financial inputs to be changed. The final budget model used in this study is a whole farm, multi-period budget model based on assumptions, parameters and values. All of which were validated during the group discussion. The typical farm simulated had an IRR of -3.22% and an NPV of -R66 405 812.70.

To assess the financial implications of regenerative farming practices on future crop and animal production in the Southern Cape, various changes were simulated using scenario planning. Discussion group participants identified three scenarios considered as a point of departure in the transition from a typical CA farming system to a regenerative system. An annual reduction of 10% in the amount of N applied, a carrying capacity of 5.5 SSU/ha, a sliding feed scale and a crop/livestock ratio of 70/30 were the most profitable suggestions made to the typical farm over a period of 20 years. Each of these changes showed positive financial implications on future crop and livestock production on a typical CA farm in the Western Rûens. Changes made to the machine inventory had a negative effect on whole-farm profitability. A fourth scenario was considered to assess the cumulative financial implications of each of the most profitable preceding production scenarios. The cumulative changes made to the typical farming system showed a positive effect on whole-farm profitability. The IRR and

NPV in the subsequent state of the typical farm, in the fourth scenario, were -2.29% and -R64 372 818.85 respectively.

The aim of this study was achieved through the simulation of the financial implications of regenerative farming practices. Changes made in accordance with regenerative principles, had a positive effect on the profitability of a typical farming system in the Western Rûens. As an explorative study, the results and findings of this study do not provide definitive answers regarding the best solution for specific farming systems. It can provide farmers and industry stakeholders with the means to speculate and to assess the financial implications of various regenerative farming practices and management strategies. Furthermore, the results and findings of this study were most applicable to farming systems in the Western Rûens but certain inferences could be made for farming systems subject to similar production conditions in other parts of the Southern Cape.

Winter cereal crop and livestock production managed in accordance with certain purely regenerative principles could hypothetically result in a higher IRR and NPV than a typical farm in the Western Rûens in its initial conservational farming orientation. It is important to note that this result is subject to the finite assumptions and parameters selected for the initial state of a typical farm in this study. Similarly, the typical farming system simulated in this study has the potential to reduce farmer input costs, improve agro-ecological synergies and increase whole-farm profit margins in the long-term. These suggestions are assumed to be within the confines of *ceteris paribus* conditions.

The success of implementing a situation specific farming system such as regenerative agriculture without full-length trials will likely be subject to farmers overcoming potential barriers. During the group discussion, participants confirmed that there are potential barriers to regenerative agriculture for producers in the Western Rûens. Possible barriers that farmers may face are time, management approach and appetite for risk. Regenerative principles take time to influence production, which can affect the short- and medium-term profitability of a farming system. Decreases in inorganic inputs such as N or livestock anti-biotics can result in less marketable farm outputs which can affect both the cash flow and profitability of a whole farming system. In the short term, it is also likely that a gradual increase in pest and weed prevalence will arise due to a reduction in the amount of synthetic inputs being used to maintain a balance in the agro-ecological environment.

On an operational level, regenerative agriculture principles require a more intensive management approach to the farming environment than conventional or conservation agriculture principles do. For example, under high or ultra-high-density grazing, a considerable amount of planning is required to ensure enough grazing to sustain the livestock and enough labour to shift livestock at regular intervals throughout the year. Often, creating the optimal crop rotation and planning schedules require significant technical expertise, which can in some cases be costly. Additionally, the establishment of cover crops poses a significant challenge for small to medium scale farmers as the profit margins of a cropping system may be smaller. Farmers with lower profit margins will likely face a financial trade-off when managing the risks involved with the establishment of cover crops and foregoing the planting of cash crops.

5.2 Summary

Dryland farming systems in the Southern Cape largely rely on external inputs to function in a financially feasible manner. In recent years, the prices of key farming inputs have begun to put the profitability of farms in the Southern Cape under pressure. In 2019, a trial was started by the Western Cape government to assess the possibilities of soil regeneration and the subsequent impact thereof on crop and livestock production in the Southern Cape. This trial can be considered as pioneering research for regenerative farming possibilities in the Southern Cape. To this end, the trial served as a point of reference for this study and for the simulation of potential production scenarios in Chapter 4. Conceptually, regenerative agriculture consists of a set of farming principles that are structured to closely mimic biological processes and nutrient cycles to create a complementary relationship between agriculture and nature.

In Chapter 2, the theoretical concepts related to the holistic approach of regenerative and systems thinking in an agricultural context were unpacked in the discussion and applied to the idea of introducing purely regenerative farming practises to winter cereal farming systems in the Southern Cape. This was done by organising existing literature into seven parts and reviewing the key aspects of regenerative agriculture and systems thinking. The first part detailed the significance of crop and livestock farming in the Western Cape. Parts Two and Three contextualised the progressive nature and value of regenerative farming and thinking in the context of modern agriculture. Parts Four and Five addressed the importance of a whole-farm system approach to agriculture, the farm decision-making environment and in modelling farming systems. The final two parts of Chapter 2 entailed a discussion on the conceptual applicability of budgeting and multidisciplinary discussion groups in assessing the financial implications of regenerative agriculture on future crop and livestock production in the Southern Cape. By adhering to a logical sequence in reviewing the theoretical concepts on the holistic approach of regenerative and systems thinking in an agricultural context, key insights into this study were gained.

In Chapter 3, some of the concepts discussed in Chapter 2 were applied to the farm level and explained according to the thought processes that underpin the financial implications of regenerative agriculture in the Southern Cape. Chapter 3 consisted of five sections regarding the geographical context of the study, typical farm theory, structure of a budget model and the applicability of scenario planning to this study. Typical farm theory was employed as a tool to simulate various production scenarios that CA-like farming systems in the Western Rûens homogenous farming area may face when moving to purely regenerative farming practices. The third and fourth section of this chapter outlined the basic structure of a budget model and the functional role of a multidisciplinary group discussion in validating the assumptions and parameters of the budget model. The explorative nature of this study was well suited to the use of simulation modelling where experimental and hypothetical changes could be made to a simulated conservational farming system in the Southern Cape. A multidisciplinary group discussion was held. Local experts and farmers in the Western Rûens combined their knowledge and experience on the hypothetical production possibilities surrounding the incorporation of purely regenerative farming practices into Southern Cape farming systems. The discussion group participants gave attention to detail regarding the verification of the parameters and assumptions surrounding the factors that might constitute a typical farm in the Western Rûens. The chapter concluded with a discussion on the use of financial indicators in a whole-farm budget model to assess various production scenarios on future crop and animal production in the Southern Cape under a regenerative farming orientation.

Chapter 4 consisted of two sections. In the first, the final budget model used in this study was explained in detail according to the assumptions, parameters and values validated during the group discussion. To calculate the revenue generated by the crop and livestock enterprises, three- and five-year averages were calculated and used to determine the cash crop, wool and meat market prices. The use of average prices in a multi-period budget model prevented external price shocks from distorting future cash flow forecasts for the typical farm. In the second section, the effect that various changes had on whole-farm profitability of the typical farm were simulated using scenario planning. Scenario planning was used to construct various changes made to the initial state of the typical farm. The financial risk tolerance was then measured according to the percentage change in whole-farm profitability indicators in the subsequent state. The initial state of the typical farm simulated had an IRR of -3.22% and an NPV of -R66 405 812.70.

Discussion group participants suggested a gradual reduction in the annual amount of N applied, a change in livestock management and machinery adjustments as key areas. These changes could have positive financial implications on future crop and livestock production on a typical CA farm in the Western Rûens undergoing the transition to regenerative farming. Each scenario was based on the financial implication it imposed on the whole-farm profitability indicators of a typical farm. The net present value (NPV) and the internal rate of return (IRR) served as indicators of profitability and measured the impact that each of the scenarios assessed had on whole-farm profitability over a period of 20 years. An annual reduction of 10% in the amount of N applied, a carrying capacity of 5.5 SSU/ha, a sliding feed scale and a crop/livestock ratio of 70/30 were the most profitable changes made to the typical farm over a period of 20 years. While each of these changes had positive financial implications on future crop and livestock production on a typical CA farm in the Western Rûens, changes made to the machine inventory had a negative effect on whole-farm profitability. A fourth scenario was used to simultaneously assess the financial implications of each of the most profitable preceding production scenarios. The accumulative changes made to the typical farming system had a positive effect on whole-farm profitability. The IRR and NPV in the subsequent state of the typical farm were -2.29% and -R64 372 818.85 respectively.

5.3 Recommendations

Limitations on time and resources restricted the scope of this study to a selection of the most likely scenarios forecasted during the multidisciplinary group discussion. More potential production scenarios relevant to a typical CA-based farm in the Western Rûens undergoing a transition to regenerative agriculture, can be investigated. Future research aimed at exploring the financial feasibility of incorporating regenerative practices on typical CA-based farms in the Western Rûens, could attempt to explore additional production scenarios on both a macro-economic and farm level. An additional point of departure for future research attempting to build on this study could be to incorporate the broad definition of regenerative agriculture outlined above with neoteric literature and updated information from the relevant industry experts and farmers. The soil regeneration trial discussed in Section 3.1.1.1 is also likely to be a future source of reliable information for additional research on regenerative agriculture in the Western Rûens area.

Farm systems with two or more enterprises can become complex to simulate as there are numerous variables that need to be accounted for. In this regard, the assumptions and parameters regarding the typical farm were made, and the aspects unaccounted-for were assumed to remain constant under *ceteris paribus* conditions. Future research on the simulation of regenerative agriculture in the Southern Cape could aim to calculate and allocate a financial value to the feed generated by cover crops. This information would support a more detailed assessment of the possible increases in livestock carrying capacities. During this study, sufficient historical data on the carrying capacity of summer cover crops in the Western Rûens was not yet available under high density grazing management practices. By adding a financial value to the feed value of a cover crop in a good, fair and poor rainfall, the ability of the simulation model to assess the long-term financial implications of the addition or subtraction of a cover crop (winter or summer) would be greatly improved.

The long-term success of agro-ecologically based farming systems, such as regenerative agriculture, would likely rest on its ability to sequester Carbon. Future research surrounding the practical methods on how this can be achieved in an efficient and effective manner, on a farm level, could have the potential to offer solutions to current climatic and financial challenges faced in the farming environment.

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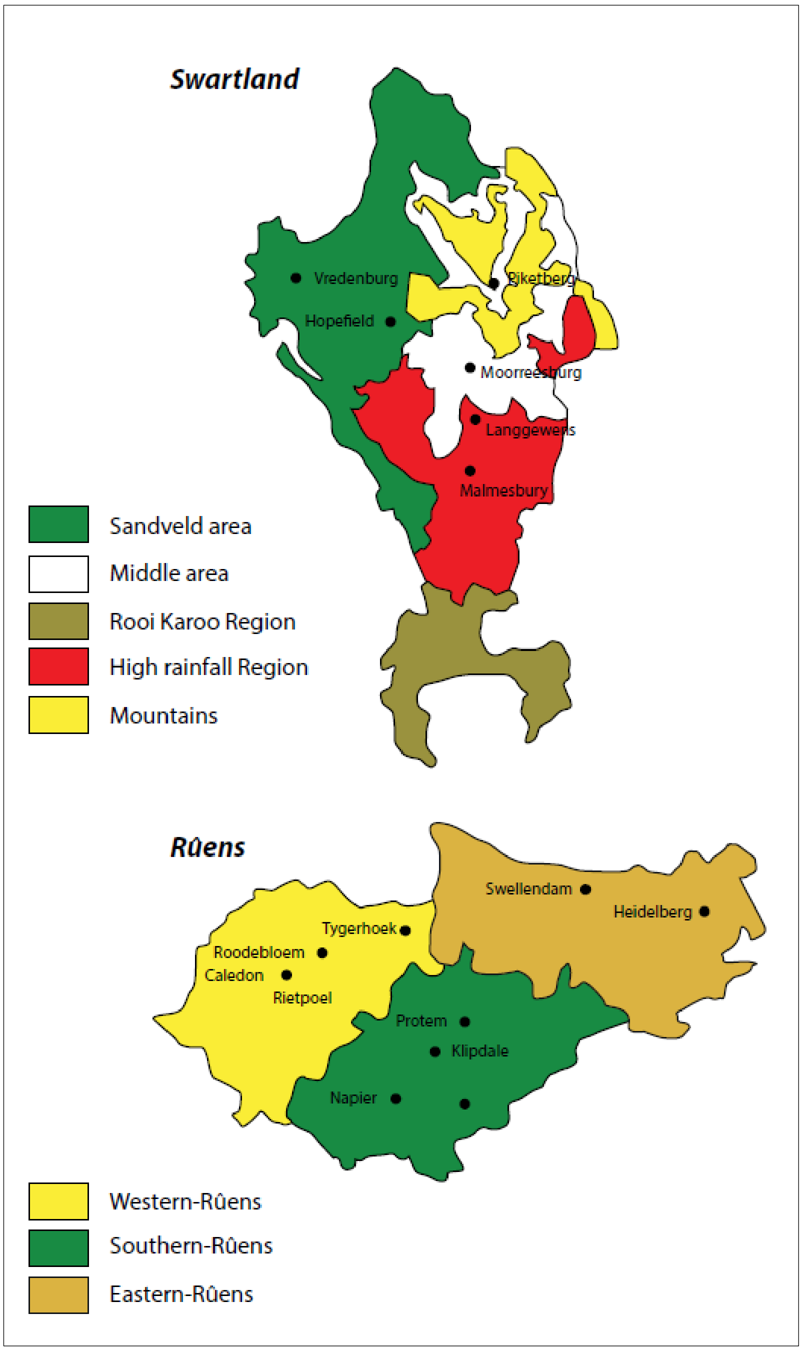
Personal communications

Communication with the following references took place in the form of direct communication or written communication.

1. Du Toit, CD. 2020. Written communication. 15 October 2020. Producer. Western Rûens, Southern Cape.
2. Gregory, M. 2020. Written communication. 1 June 2020. Agricultural Advisor, Overberg Agri.
3. Hoffmann, W. 2020. Direct communication. Multidisciplinary Discussion Group. 30 September 2020. Agricultural Economist, Stellenbosch University.
4. Nell, C. 2020. Written communication. 1 June 2020. Agricultural Advisor, Overberg Agri.
5. Pretorius, W. 2020. Written communication. 13 May 2020. Soil expert at Soil Health Solutions.
6. Smorenburg, L. 2020. Written communication. 3 June 2020. Scientific Technician, Grade C, Tygerhoek Research Farm, Western Cape Department of Agriculture.
7. Strauss, J. 2020a. Written communication. 24 April 2020. Agronomist, Western Cape Department of Agriculture.
8. Strauss, J. 2020b. Direct communication. Multidisciplinary Discussion Group. 30 September 2020. Agronomist, Western Cape Department of Agriculture.

Appendices

Annexure A: Small grain production areas in the winter rainfall region of the Western Cape.



Source: ARC Small Grain Institute (2020)

Annexure B: An example of a multi-period capital budget for a typical farm in the Western Rûens from 2020 to 2039

Whole farm multi-period capital budget

Enterpise		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	
Gross Margin: Canola		R -	R -	R -	R -	R -	R -	R -	R 97 160,59	R 244 910,45	R 392 660,31	R -	R -	R -	R -	R -	R -	R -	R 97 160,59	R -	R -	
Gross Margin: Wheat		R -	R -	R -	R -	R -	R 859 795,59	R 520 278,96	R -	R 520 278,96	R 859 795,59	R 520 278,96	R -	R 859 795,59	R -	R -	R 859 795,59	R -	R -	R 520 278,96	R 859 795,59	
Gross Margin: Barley		R -	R -	R -	R -	R -	R -	R 831 342,65	R 404 527,17	R 831 342,65	R 1 258 158,12	R 831 342,65	R 831 342,65	R -	R 1 258 158,12	R -	R -	R 831 342,65	R -	R -	R 1 258 158,12	
Gross Margin: Pastures		R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	
Gross Margin: Oats		R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 74 095,74	R -	R -	R -	R -	R -	R -	R -	
Gross Margin: Lupins		R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	-R 2 368,74	R -	R -	R -	R -	R -	R -	R -	R -	
Gross Margin: Sheep		R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	
Capital sales		R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	
Total farm gross margin		**R 125 722,74**	**R 125 722,74**	**R 125 722,74**	**R 125 722,74**	**R 125 722,74**	**R 985 518,34**	**R 1 477 344,35**	**R 627 410,50**	**R 1 722 254,80**	**R 2 636 336,76**	**R 1 477 344,35**	**R 954 696,64**	**R 1 059 614,08**	**R 1 383 880,86**	**R 125 722,74**	**R 985 518,34**	**R 957 065,39**	**R 222 883,33**	**R 646 001,70**	**R 2 243 676,46**	
Fixed Costs																						
Permanent labour		R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	R 583 253,00	
Bank charges		R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	R 28 655,00	
Farm miscellaneous		R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	R 417 472,00	
Consultations		R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	R 72 259,00	
Fixed improvements		R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	R 342 221,00	
Electricity		R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	R 324 000,00	
Water rights		R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	R 51 600,00	
Municiple tax		R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	
Communication		R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	R 2 400,00	
Advance: Irrigation		R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	
Auditors fee		R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	R 24 000,00	
Insurance on assets		R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	R 6 000,00	
Total Fixed costs		**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	**R 1 863 860,00**	
Net Farm Income (Gross Margin after fixed costs)		**-R 1 738 137,26**	**-R 1 738 137,26**	**-R 1 738 137,26**	**-R 1 738 137,26**	**-R 1 738 137,26**	**-R 878 341,66**	**-R 386 515,65**	**-R 1 236 449,50**	**-R 141 605,20**	**R 772 476,76**	**-R 386 515,65**	**-R 909 163,36**	**-R 804 245,92**	**-R 479 979,14**	**-R 1 738 137,26**	**-R 878 341,66**	**-R 906 794,61**	**-R 1 640 976,67**	**-R 1 217 858,30**	**R 379 816,46**	
External Factor costs																						
Rent		R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	
Owner/management salary		R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	R 257 092,00	
Interest on capital borrowed		R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	
Total external factor costs		**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	**R 257 092,00**	
Gross margin after external factor costs		**-R 1 995 229,26**	**-R 1 995 229,26**	**-R 1 995 229,26**	**-R 1 995 229,26**	**-R 1 995 229,26**	**-R 1 135 433,66**	**-R 643 607,65**	**-R 1 493 541,50**	**-R 398 697,20**	**R 515 384,76**	**-R 643 607,65**	**-R 1 166 255,36**	**-R 1 061 337,92**	**-R 737 071,14**	**-R 1 995 229,26**	**-R 1 135 433,66**	**-R 1 163 886,61**	**-R 1 898 068,67**	**-R 1 474 950,30**	**R 122 724,46**	
Capital outlay:																						
Fixed assets																						**Present value in 2039**
Farm land owned and fixed improvements		R 45 593 000,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 45 593 000,00
Moveable assets																						
Tractors kW (4x4)																						
240		R 298 208,33	R 3 220 650,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 3 220 650,00	R -	R -	R -	R -	R -	R 2 683 875,00
125		R 677 291,67	R -	R -	R -	R -	R 1 462 950,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 1 462 950,00	R -	R 1 760 958,33
100		R 401 500,00	R -	R -	R -	R 1 084 050,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 1 084 050,00	R -	R -	R 1 204 500,00
100		R 301 125,00	R -	R -	R 1 084 050,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 1 084 050,00	R -	R -	R -	R 1 104 125,00
75		R 137 333,33	R -	R 741 600,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 741 600,00	R -	R -	R -	R -	R 686 666,67
60		R 207 000,00	R -	R -	R -	R 558 900,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 558 900,00	R -	R -	R 621 000,00
Combine Harvesters (kW)			R -																			
201 kW, 6m		R 316 666,67	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 1 583 333,33
201 kW, 6m		R 1 108 333,33	R -	R -	R -	R -	R -	R -	R 1 710 000,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 316 666,67
Vehicles			R -																			
Hilux 2.8GD-6 4X4 SRX LSD		R 415 500,00	R -	R -	R -	R -	R -	R -	R -	R -	R 498 600,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 184 666,67
Hilux 2.4 GD		R 51 550,00	R -	R 278 370,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 278 370,00	R -	R -	R -	R -	R 257 750,00
Trailers			R -																			
Trailor (10 Wheel, 10 ton)		R 17 225,00	R -	R -	R 62 010,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 62 010,00	R -	R -	R -	R 63 158,33
Trailor (10 Wheel, 10 ton)		R 5 741,67	R 62 010,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 62 010,00	R -	R -	R -	R -	R -	R 51 675,00
Bulperd Trailer (Livestock Transport)		R 33 333,33	R -	R -	R -	R -	R -	R -	R -	R 45 000,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 12 500,00
Lorry (7 ton)		R 103 732,25	R -	R -	R 373 436,10	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 373 436,10	R -	R -	R -	R 380 351,58
Implements			R -																			
Boom Sprayer (18m, 2000l)		R 56 106,67	R -	R -	R -	R 151 488,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 151 488,00	R -	R -	R 168 320,00
Boom Sprayer (18m, 3000l)		R 72 500,00	R -	R -	R 261 000,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 261 000,00	R -	R -	R -	R 265 833,33
Hay Baler (800x900cm)		R 235 774,33	R -	R -	R -	R 636 590,70	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 636 590,70	R -	R -	R 707 323,00
Fertilizer spreader (double disk 1500l)		R 35 278,50	R -	R -	R -	R -	R -	R -	R -	R -	R 42 334,20	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 15 679,33
Seed drill - no-till trailed - 15-20 rows		R 111 475,00	R -	R -	R -	R -	R -	R 200 655,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 200 655,00	R 18 579,17
Front end loader		R 59 170,83	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 58 095,00	R -	R -	R -	R -	R -	R -	R -	R -	R 32 275,00
Mowers:																						
9,2m		R 261 612,00	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 235 450,80	R -	R -	R -	R -	R -	R -	R -	R 152 607,00
11m		R 141 199,50	R -	R -	R -	R -	R -	R 254 159,10	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 254 159,10	R 23 533,25
Total moveable assets		**R 5 047 657,42**	**R 3 282 660,00**	**R 1 019 970,00**	**R 1 780 496,10**	**R 2 431 028,70**	**R 1 462 950,00**	**R 454 814,10**	**R 1 710 000,00**	**R 45 000,00**	**R 540 934,20**	**R -**	**R 58 095,00**	**R 235 450,80**	**R -**	**R 3 282 660,00**	**R 1 019 970,00**	**R 1 780 496,10**	**R 2 431 028,70**	**R 1 462 950,00**	**R 454 814,10**	R 12 295 376,67
Sheep flock value		**R 8 932 329,47**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	R 8 932 329,47
Total capital		**R 59 572 986,88**	**R 3 282 660,00**	**R 1 019 970,00**	**R 1 780 496,10**	**R 2 431 028,70**	**R 1 462 950,00**	**R 454 814,10**	**R 1 710 000,00**	**R 45 000,00**	**R 540 934,20**	**R -**	**R 58 095,00**	**R 235 450,80**	**R -**	**R 3 282 660,00**	**R 1 019 970,00**	**R 1 780 496,10**	**R 2 431 028,70**	**R 1 462 950,00**	**R 454 814,10**	R 66 820 706,13
Yearly net inflow		**-R 61 568 216,14**	**-R 5 277 889,26**	**-R 3 015 199,26**	**-R 3 775 725,36**	**-R 4 426 257,96**	**-R 2 598 383,66**	**-R 1 098 421,75**	**-R 3 203 541,50**	**-R 443 697,20**	**-R 25 549,44**	**-R 643 607,65**	**-R 1 224 350,36**	**-R 1 296 788,72**	**-R 737 071,14**	**-R 5 277 889,26**	**-R 2 155 403,66**	**-R 2 944 382,71**	**-R 4 329 097,37**	**-R 2 937 900,30**	**R 66 488 616,49**	

IRR	-3,22%
NPV	-R66 405 812,70

Annual Cashflow																					
Opening Balance		0	-3538098,513	-7712159,409	-12316043,94	-17467645,57	-23281406,09	-28206849,33	-32657664,21	-38436268,09	-43278822,34	-47291679,39	-52689802,3	-59013180,05	-65535656,99	-72196937,11	-81022478,27	-89704417,54	-99266148,32	-110586299,9	-122306340,4
Inflow		R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 125 722,74	R 985 518,34	R 1 477 344,35	R 627 410,50	R 1 722 254,80	R 2 636 336,76	R 1 477 344,35	R 954 696,64	R 1 059 614,08	R 1 383 880,86	R 125 722,74	R 985 518,34	R 957 065,39	R 222 883,33	R 646 001,70	R 2 243 676,46
Outflow		R 3 415 368,11	R 3 758 218,67	R 3 864 747,30	R 4 050 707,49	R 4 304 611,19	R 3 930 213,93	R 3 634 865,48	R 3 706 934,22	R 3 525 673,96	R 3 328 267,00	R 3 175 472,25	R 3 134 037,75	R 2 980 031,55	R 2 975 331,62	R 3 261 685,43	R 3 368 214,06	R 3 548 106,64	R 3 777 419,18	R 3 777 419,18	R 3 482 070,73
Balance before interest		-R 3 289 645,37	-R 7 170 594,44	-R 11 451 183,97	-R 16 241 028,68	-R 21 646 534,02	-R 26 226 101,68	-R 30 364 370,46	-R 35 737 187,93	-R 40 239 687,26	-R 43 970 752,57	-R 48 989 807,29	-R 54 869 143,41	-R 60 933 597,52	-R 67 127 107,75	-R 75 332 899,80	-R 83 405 174,00	-R 92 295 458,79	-R 102 820 684,17	-R 113 717 717,36	-R 123 544 734,65
Interest		-R 248 453,14	-R 541 564,97	-R 864 859,97	-R 1 226 616,89	-R 1 634 872,07	-R 1 980 747,64	-R 2 293 293,75	-R 2 699 080,16	-R 3 039 135,08	-R 3 320 926,82	-R 3 699 995,01	-R 4 144 036,64	-R 4 602 059,47	-R 5 069 829,36	-R 5 689 578,47	-R 6 299 243,54	-R 6 970 689,53	-R 7 765 615,73	-R 8 588 623,01	-R 9 330 816,48
Closing balance		-R 3 538 098,51	-R 7 712 159,41	-R 12 316 043,94	-R 17 467 645,57	-R 23 281 406,09	-R 28 206 849,33	-R 32 657 664,21	-R 38 436 268,09	-R 43 278 822,34	-R 47 291 679,39	-R 52 689 802,30	-R 59 013 180,05	-R 65 535 656,99	-R 72 196 937,11	-R 81 022 478,27	-R 89 704 417,54	-R 99 266 148,32	-R 110 586 299,89	-R 122 306 340,38	-R 132 875 551,13

Annexure C: An example of the inventory list for a typical farm in the Western Rûens.

Land owned (including fixed improvements)		
ha	R/ha	Total
1100	R 40 000,00	**R 44 000 000,00**

Fixed improvements				
	Description	**Units**	**R/Unit**	**Total**
Farmhouse	Owner's residence	1	R 510 000,00	R 510 000,00
Staff Accomodation	1 House per staff member	8	R 51 000,00	R 408 000,00
Operational buildings	Offices and equipment storage	2	R 30 000,00	R 60 000,00
Shed	1 Large shed for machinery and equipment	1	R 150 000,00	R 150 000,00
Shearing Facility	Holding pens, bale press and sorting tables	1	R 60 000,00	R 60 000,00
Water supply infrastructure	Water supply for livestock	1	R 120 000,00	R 120 000,00
Crawls (Multipurpose)	Portable, for livestock management	1	R 45 000,00	R 45 000,00
Fencing	Livestock camps	1	R 240 000,00	R 240 000,00
Total				**R 1 593 000,00**

Movable Assets						
Item	**Cost**	**Expected Age**	**Current Age**	**Depreciation at current age**	**Present Value (after depreciation)**	**Salvage value (10% of cost)**
Tractors kW (4x4)						
240	R 3 578 500,00	12	1	R 298 208,33	R 3 280 291,67	R 357 850,00
125	R 1 625 500,00	12	6	R 812 750,00	R 812 750,00	R 162 550,00
100	R 1 204 500,00	12	3	R 301 125,00	R 903 375,00	R 120 450,00
100	R 1 204 500,00	12	1	R 100 375,00	R 1 104 125,00	R 120 450,00
75	R 824 000,00	12	10	R 686 666,67	R 137 333,33	R 82 400,00
60	R 621 000,00	12	1	R 51 750,00	R 569 250,00	R 62 100,00
Combine Harvestors (kW)						
201 kW, 6m	R 1 900 000,00	12	9	R 1 425 000,00	R 475 000,00	R 190 000,00
201 kW, 6m	R 1 900 000,00	12	3	R 475 000,00	R 1 425 000,00	R 190 000,00
Mowers						
9,2m	R 261 612,00	12	0	R -	R 261 612,00	R 26 161,20
11m	R 282 399,00	12	6	R 141 199,50	R 141 199,50	R 28 239,90
Vehicles						
Hilux 2.8GD-6 4X4 SRX L50	R 554 000,00	12	4	R 184 666,67	R 369 333,33	R 55 400,00
Hilux 2.4 GD	R 309 300,00	12	3	R 77 325,00	R 231 975,00	R 30 930,00
Trailers						
Trailor (10 Wheel, 10 ton)	R 68 900,00	12	9	R 51 675,00	R 17 225,00	R 6 890,00
Trailor (10 Wheel, 10 ton)	R 68 900,00	12	11	R 63 158,33	R 5 741,67	R 6 890,00
Bulperd Trailer (Livestock Transport)	R 50 000,00	12	4	R 16 666,67	R 33 333,33	R 5 000,00
Lorry (7 ton)	R 414 929,00	12	9	R 311 196,75	R 103 732,25	R 41 492,90
Implements						
Boom Sprayer (18m, 2000l)	R 168 320,00	12	8	R 112 213,33	R 56 106,67	R 16 832,00
Boom Sprayer (18m, 3000l)	R 290 000,00	12	9	R 217 500,00	R 72 500,00	R 29 000,00
Hay Baler (800x900cm)	R 707 323,00	18	8	R 314 365,78	R 392 957,22	R 70 732,30
Fertilizer spreader (double disk 1500l)	R 47 038,00	12	3	R 11 759,50	R 35 278,50	R 4 703,80
Seed drill - no-till trailed - 15-20 rows	R 222 950,00	12	6	R 111 475,00	R 111 475,00	R 22 295,00
Front end loader	R 64 550,00	12	2	R 10 758,33	R 53 791,67	R 6 455,00
CA Equipment Total	**R 16 368 221,00**				**R 10 593 386,14**	**R 1 636 822,10**

Sheep flock count						
Breed: Dhone Merino						
Animal Classification		Count	R/kg (on the hook)	Average weight (kg)	Value per ha	Total
Merino sheep	Rams	37	R 51,70	60	R 3 102,00	R 113 790,78
	Ewes - Productive	1467	R 54,96	55	R 3 022,80	R 4 435 419,21
	Old ewes for finishing and termination	220	R 51,70	70	R 3 619,00	R 796 535,44
	Replacement ewes	293	R 54,96	55	R 3 022,80	R 887 083,84
	Weaner lambs	1614	R 69,49	27	R 1 876,23	R 3 028 335,73
Total		**3632**				**R 9 261 165,00**

Total assets	**R 65 447 551,14**

Annexure D: An example of a machine replacement schedule for a typical farm in the Western Rûens.

Machinery	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Tractors kW (4x4)																				
240	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10	9	8
125	5	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12
100	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11
100	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10
75	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10	9
60	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11
Combine Harvestors (kW)																				
201 kW, 6m	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10	9
201 kW, 6m	7	6	5	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1
Vehicles																				
Hilux 2.8GD-6 4X4 SRX L50	9	8	7	6	5	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3
Hilux 2.4 GD	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10	9
Trailers																				
Trailor (10 Wheel, 10 ton)	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10
Trailor (10 Wheel, 10 ton)	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10	9	8
Bulperd Trailer (Livestock Transport)	8	7	6	5	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2
Lorry (7 ton)	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10
Implements																				
Boom Sprayer (18m, 2000l)	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11
Boom Sprayer (18m, 3000l)	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10
Hay Baler (800x900cm)	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11
Fertilizer spreader (double disk 1500l)	9	8	7	6	5	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3
Seed drill - no-till trailed - 15-20 rows	6	5	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0
Front end loader	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10	9	8	7	6	5
Mowers:																				
9,2m	12	11	10	9	8	7	6	5	4	3	2	1	0	12	11	10	9	8	7	6
11m	6	5	4	3	2	1	0	12	11	10	9	8	7	6	5	4	3	2	1	0
Number of implements to replace per year	**0**	**2**	**3**	**4**	**4**	**1**	**2**	**1**	**1**	**2**	**0**	**1**	**1**	**0**	**2**	**3**	**4**	**4**	**1**	**2**

Key	
0	Replace
Numbers	Years left before replaced

Annexure E: An example of a crop rotation schedule for a typical farm in the Western Rûens.

Crop rotation schedule																				
Systems	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**
System 1	Pastures	Pastures	Pastures	Pastures	Pastures	Wheat	Barley	Canola	Wheat	Barley	Pastures	Pastures	Pastures	Pastures	Pastures	Wheat	Barley	Canola	Wheat	Barley
System 2	Pastures	Pastures	Pastures	Pastures	Pastures	Pastures	Wheat	Barley	Barley	Canola	Wheat	Barley	Oats	Pastures	Pastures	Pastures	Pastures	Pastures	Pastures	Wheat
System 3	Pastures	Pastures	Pastures	Pastures	Pastures	Pastures	Wheat	Barley	Canola	Wheat	Barley	Lupins	Wheat	Barley	Pastures	Pastures	Pastures	Pastures	Pastures	Pastures
Crop																				
Canola	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0
Wheat	0	0	0	0	0	1	1	0	1	1	1	0	1	0	0	1	0	0	1	1
Barley	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	1	0	0	1
Pastures	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1
Oats	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lupins	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Key	
1	Plant crop
0	Crop not planted

Annexure F: An example of an enterprise gross margin calculation for Canola on a typical farm in the Western Rûens.

Canola

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Predicted yield according to rainfall	Fair	Fair	Good	Good	Good	Good	Fair	Poor	Fair	Good
Crop yield	1,76	1,76	2,2	2,2	2,2	2,2	1,76	1,32	1,76	2,2
Gross income										
Sales Revenue	R -	R -	R -	R -	R -	R -	R -	R 7 813,52	R 10 418,02	R 13 022,53
Insurance payout received	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Own use	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Staff use	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Stock adjustment	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Total gross income	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 7 813,52**	**R 10 418,02**	**R 13 022,53**
Directly allocatable costs										
Seed	R -	R -	R -	R -	R -	R -	R -	R 817,50	R 817,50	R 817,50
Fertiliser	R -	R -	R -	R -	R -	R -	R -	R 1 944,51	R 1 944,51	R 1 944,51
Weed management	R -	R -	R -	R -	R -	R -	R -	R 532,88	R 532,88	R 532,88
Fungi Control	R -	R -	R -	R -	R -	R -	R -	R 482,95	R 482,95	R 482,95
Insect control	R -	R -	R -	R -	R -	R -	R -	R 767,09	R 767,09	R 767,09
Trace elements	R -	R -	R -	R -	R -	R -	R -	R 76,00	R 76,00	R 76,00
Water costs	R -	R -	R -	R -	R -	R -	R -	R 23,64	R 23,64	R 23,64
Contract services	R -	R -	R -	R -	R -	R -	R -	R 39,17	R 39,17	R 39,17
Casual labour	R -	R -	R -	R -	R -	R -	R -	R 6,63	R 6,63	R 6,63
Statuatory levies and silo costs	R -	R -	R -	R -	R -	R -	R -	R 34,61	R 34,61	R 34,61
Soil and plant analysis, Mapping	R -	R -	R -	R -	R -	R -	R -	R 86,50	R 86,50	R 86,50
Insurance - Fire and SASRIA	R -	R -	R -	R -	R -	R -	R -	R 22,75	R 22,75	R 22,75
Yield insurance	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Total directly allocatable costs	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 4 834,23**	**R 4 834,23**	**R 4 834,23**
Non-directly allocatable costs										
Fuel use - litres	0	0	0	0	0	0	0	44,71	44,71	44,71
Fuel cost	R -	R -	R -	R -	R -	R -	R -	R 549,04	R 549,04	R 549,04
Repairs and maintenance	R -	R -	R -	R -	R -	R -	R -	R 717,52	R 717,52	R 717,52
Total non-directly allocatable costs	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 1 266,56**	**R 1 266,56**	**R 1 266,56**
Total variable costs	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 6 100,79**	**R 6 100,79**	**R 6 100,79**
Gross margin per ha	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 1 712,73**	**R 4 317,23**	**R 6 921,74**
Gross margin for all Canola planted	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 97 160,59**	**R 244 910,45**	**R 392 660,31**

	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Predicted yield according to rainfall	Fair	Fair	Good	Good	Good	Good	Fair	Poor	Fair	Good
Crop yield	1,76	1,76	2,2	2,2	2,2	2,2	1,76	1,32	1,76	2,2
Gross income										
Sales Revenue	R -	R -	R -	R -	R -	R -	R -	R 7 813,52	R -	R -
Insurance payout received	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Own use	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Staff use	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Stock adjustment	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Total gross income	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 7 813,52**	**R -**	**R -**
Directly allocatable costs										
Seed	R -	R -	R -	R -	R -	R -	R -	R 817,50	R -	R -
Fertiliser	R -	R -	R -	R -	R -	R -	R -	R 1 944,51	R -	R -
Weed management	R -	R -	R -	R -	R -	R -	R -	R 532,88	R -	R -
Fungi Control	R -	R -	R -	R -	R -	R -	R -	R 482,95	R -	R -
Insect control	R -	R -	R -	R -	R -	R -	R -	R 767,09	R -	R -
Trace elements	R -	R -	R -	R -	R -	R -	R -	R 76,00	R -	R -
Water costs	R -	R -	R -	R -	R -	R -	R -	R 23,64	R -	R -
Contract services	R -	R -	R -	R -	R -	R -	R -	R 39,17	R -	R -
Casual labour	R -	R -	R -	R -	R -	R -	R -	R 6,63	R -	R -
Statuatory levies and silo costs	R -	R -	R -	R -	R -	R -	R -	R 34,61	R -	R -
Soil and plant analysis, Mapping	R -	R -	R -	R -	R -	R -	R -	R 86,50	R -	R -
Insurance - Fire and SASRIA	R -	R -	R -	R -	R -	R -	R -	R 22,75	R -	R -
Yield insurance	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Total directly allocatable costs	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 4 834,23**	**R -**	**R -**
Non-directly allocatable costs										
Fuel use - litres	0	0	0	0	0	0	0	44,71	0	0
Fuel cost	R -	R -	R -	R -	R -	R -	R -	R 549,04	R -	R -
Repairs and maintenance	R -	R -	R -	R -	R -	R -	R -	R 717,52	R -	R -
Total non-directly allocatable costs	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 1 266,56**	**R -**	**R -**
Total variable costs	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 6 100,79**	**R -**	**R -**
Gross margin per ha	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 1 712,73**	**R -**	**R -**
Gross margin for all Canola planted	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R 97 160,59**	**R -**	**R -**